[Journal of Ocean and Coastal Economics](https://cbe.miis.edu/joce)

Volume 8 | Issue 1 Article 1

Eelgrass Restoration in San Francisco Bay: An Interdisciplinary Stated Preference Classroom Experiment

Camille M. Antinori
San Francisco State University

Recommended Citation

Antinori, Camille M. () "Eelgrass Restoration in San Francisco Bay: An Interdisciplinary Stated Preference Classroom Experiment," *Journal of Ocean and Coastal Economics*: Vol. 8: Iss. 1, Article 1.
DOI: https://doi.org/10.15351/2373-8456.1133

Eelgrass Restoration in San Francisco Bay: An Interdisciplinary Stated Preference Classroom Experiment

Acknowledgments

The author wishes to thank the SFSU Fall 2019 Econ 550/850 class (Alejandra Barbero Ortega, Eduardo Alberto Bernardo Garcia, Barbora Buzinskaite, Rezzo Calamucha, Connor Carinio, Guadalupe Carrasco, Brandon Chu, Aidan Cushing, Agathe Denoyer, Dakota Fischer, Randy Fu, Jacob Jaramillo, Taylor Johnson, Yaoqun Li, Joshua Llanos, Andrea Madrid, Wei Mou, Patrick Noder, Ricardo Ortega Requena, Christian Sanchez, Katharina Scheiter, Leonhard Schoeffel, Austin Schutz, Brandon Seanez, Chiho Shida, Ana Tienda Marin, Abby Wilson and Yun Xie) for their participation, Dakota Fischer for additional research assistance, Gary Casterline for invaluable technical support, and Anoshua Chaudhuri for encouragement and gracious review of earlier drafts. A debt is also acknowledged to Dr. Karina Nielsen, Director of the Estuary Ocean Science Center, who made the field trip possible and all scientists who took time with students during the tour. This work was supported by a grant from the Lam Family College of Business, San Francisco State University.

1. INTRODUCTION

The burgeoning science of sustainable oceans and the blue economy has brought the need for educational institutions to prepare economics students for research and practice in ocean and coastal related issues. Such education places a premium on interdisciplinary discourse to generate meaningful research, models and tools applicable to dealing with the complex linkages of oceans and the economy (Zilberman, 1994; Goldsmith, 2018; Colander and McGoldrick, 2010) often unfamiliar to the general population (Börger et al., 2018; Maritime Affairs, 2020; Hanley et al., 2015). “Interdisciplinary” here is defined as “any study or group of studies undertaken by scholars from two or more distinct scientific disciplines” (Harvard School of Public Health, 2020).[1] It has been noted (Börger et al., p. 148) that understanding and quantifying environmental changes call for close cooperation between economists and natural scientists, where the economists provide information on the social desirability of change while the natural scientists provide information on the management measures that lead to that change. Ocean and coastal zones as foundations for climate resiliency and economic productivity are little represented in the basic examples, models, and policy tools taught in undergraduate environmental economics courses.

To fill this gap, this paper presents a classroom experiment in stated preference (SP) that purposefully builds interdisciplinary skills in oceans sciences application and collaboration into an undergraduate environmental economics curriculum. In consultation with scientists at San Francisco State University’s Estuary & Ocean Science Center (EOS Center), a SP exercise using contingent valuation (CV) method was integrated into the Environmental Economics (Econ 550), Fall 2019 course curriculum. Students collaboratively chose and developed a survey instrument on eelgrass restoration. Eelgrass is a form of seagrass that has important contributions to ecosystems, such as fish and bird habitat, as well as carbon sequestration potential. Estimates show its carbon storage on par or surpassing temperate and tropical forests, mangroves and tidal marshes, yet it is experiencing a high global loss rate (Bedulli et al., 2020; Duarte et al., 2005, 2013; Hoegh-Guldberg, 2019; Audubon California, 2018). For this

[1]Harvard School of Public Health goes on to describe interdisciplinary as “based upon a conceptual model that links or integrates theoretical frameworks from those disciplines, uses study design and methodology that is not limited to any one field, and requires the use of perspectives and skills of the involved disciplines throughout multiple phases of the research process.” This is distinguished from “transdisciplinary” research which is defined as research efforts conducted by investigators from different disciplines working jointly to create new conceptual, theoretical, methodological, and translational innovations that integrate and move beyond discipline-specific approaches to address a common problem” (Harvard School of Public Health, 2020).

reason, eelgrass projects are being considered in carbon trading projects (Audubon California; Duarte et al., 2005). Coordinating the classroom project with ecologists at the EOS Center, created interdisciplinary foundations and collaborative pathways between economists and natural scientists for valuing marine ecosystems. The experiment also has the benefit of coinciding with "high-impact" educational practices, as it incorporates community-based, experiential learning and collaborative assignments (NSSE, 2018).

The paper is organized as follows. We begin with a literature review first on seagrass stated preference studies to report how these projects are structured, communicated and evaluated and second on pedagogical examples of stated preference conducted in the classroom. The third section lays out the steps in the classroom eelgrass valuation project, pointing out how natural science and economics overlapped in its progression. The fourth section presents results of the willingness-to-pay measures using open-ended and closed-ended willingness-to-pay (WTP) elicitation formats, with a double-bounded dichotomous choice model extended here for illustration. While the sampling was biased given who students accessed for interviews, the WTP results are on par with existing eelgrass bed valuation studies. Student feedback is given in the fifth section, with discussion of strengths and weaknesses from both instructor and students' points of view.

2. LITERATURE REVIEW

2.1 Stated Preference Eelgrass Valuations

Seagrass beds are highly productive coastal ecosystems which have received growing attention in the blue economy literature for their potential contribution to climate change mitigation (Alcamo and Bennett, 2003; Costanza et al., 1997). Reports have referred to them as "hot spots" for carbon sequestration, storing carbon at a rate 10 times larger per hectare than terrestrial ecosystems as saltwater slows decomposition of organic matter, leading to a build-up of carbon stock in marine soil sediment (Hoegh-Guldberg, p. 48). Estimates put seagrass coverage at about 325,000 square kilometers across the globe and current rates of loss at 2-7% per year as of 2018 (Hoegh-Guldberg, p. 53), with possibly 29% of known global coverage already lost or degraded (Mehvar et al., 2018, p. 11). Cole and Moksnes (2016) estimate that 15.4 tC would be lost per hectare if eelgrass beds *Zostera marina* were degraded in the Atlantic, also eliminating sequestering potential of an additional 1.66 tC per year (p. 68). Seagrass bed conservation could lead to avoided emissions of 0.65 Gt CO2 per year, while restoration activities have the potential of recovering 9000 square kilometers of seagrass and sequester 0.01 Gt CO2 per year or more (Hoegh-Guldberg,

DOI: 10.15351/2373-8456.1133

p. 50).

Since the presence of seagrass can lead to intermediate changes in the environment due to its impact on other outcomes, eelgrass can be valued for direct and indirect use and nonuse values (Johnston et al., 2017a, p. 327). The review in Raheem et al. (2009, p. 20) found a distinct knowledge gap in valuation studies for coastal ecosystem goods and services, pointing to a need for original economic research on these services. However, for stated preference studies, the linkages between a species or system and any final outcome, like water clarity, requires that researchers present such linkages in ways that respondents understand (Johnston et al., 2017a,b). Each of the studies listed in Table 1 uses a different approach, and several used multiple approaches within the one study and represent multidisciplinary programs.

Table 1: Eelgrass Studies Using Stated Preference Methods

Source	Location	Models	Value
Johnston et al. (2002)	Peconic Estuary System, NY	productivity model, contingent choice experiment	marginal productivity value: $1,065/acre/yr.; total asset value: $12,412/acre over 25 years; WTP equivalent to $6003/acre/yr.
Raheem et al. (2009)	California	nutrient recycling replacement value	$11,188/acre/yr. based on Costanza et al.
Han et al. (2008)	Hepu area of Guangxi Province, China	fishing value, benefit transfer, CV	$17.88/ha/yr.
Cole and Moksnes (2016)	Sweden	nutrient recycling replacement cost, social carbon cost of carbon, value of fisheries	$20,700/ha over 20-50, annualized to $1300/ha/yr.
Wallmo and Lew (2015)	U.S. national and west coast	choice experiment	$41.36 - $43.83
Börger and Piwowarczyk, (2016)	Gulf of Gdańsk, Poland	choice experiment	$18.00/yr.

The lack of familiarity among the general public with the marine environment highlights a number of underlying issues for stated preference studies, particularly for aquatic plants and their ecosystems (Börger et al.; Hanley et al.). Lew (2015) reviewed the valuation literature on threatened, endangered and rare (TER) marine species and found that valuations applied to *aggregate* groups of species or specialized programs rendered the transfer of values difficult for any one species. In the study by Wallmo and Lew (2015) on TERs, 65% of respondents indicated that they were "not familiar at all" with Johnson's eelgrass, (*Halophila johnsonii*), a threatened species of eelgrass native to southeastern Florida. The next highest percentage of unfamiliarity was 57% for Elkhorn coral, then 53% for California steelhead trout. Their stated preference experiment yields a mean WTP for Johnson's eelgrass of $43.83 for a national sample and $41.36 for a west coast sample, the lowest WTP values among the TER species in the study. These results possibly reflect scope sensitivity, as endangered species were valued higher on average than threatened species (p. 31). Across most species in the study, they found no significant difference in WTP estimates between the national and west coast samples, concluding that the economic jurisdiction for WTP studies for TER policy should cover the entire United States.

In a paper on point with the purpose of this study but aimed at natural scientists, Börger et al. argue for more intentional interdisciplinary collaboration in stated preference research to value marine environmental goods and use, among other examples, a discrete choice experiment in Poland for valuing a restoration project for *Zostera marina*, the same eelgrass species as in the present study. A team of two economists and three seagrass ecologists coordinated efforts to design levels of policy interventions that affected eelgrass growth based on reduced algal blooms, recreational access and water purification, with payments made through household fees for wastewater treatment (Börger and Piwowarczyk, 2016). They note a tension between approaches by scientists versus economists concerning certainty in the impact of environmental changes (Börger et al., p. 148). These changes may be uncertain scientifically, but are regularly presented as being certain within the stated preference scenario, pointing to a need for better information from natural scientists relating types of uncertainty to environmental change. Another interdisciplinary policy application for eelgrass valuation studies is that any value placed on water quality and reduced algal blooms as outcomes of eelgrass bed restoration/conservation could be transferred to other sites for valuing those environmental outcomes independent of eelgrass beds themselves, provided that scientists could evaluate transferability to a proposed site (Börger et al., p. 149).

2.2 Stated Preference Classroom Experiments

The opportunity to introduce SP with experiential learning and community engagement exercises has not been lost on undergraduate environmental economics instructors. Reviewing the pedagogical examples of stated preference activities, interdisciplinary research was indispensable in generating the valuation scenarios even if such skill-building was not a primary learning objective. This section highlights collaborative processes and interdisciplinary activities where students engage with noneconomic scholars or bodies of knowledge.

Interestingly, undergraduate classroom SP projects are often not intentionally interdisciplinary but call upon other knowledge bases to come to fruition. Andrews (2001) describes a class contingent valuation undergraduate class experiment on water quality improvements in the Brandywine River in Pennsylvania. Students researched state and EPA scientific reports on local water quality to determine how policy interventions would deliver the changes proposed in their survey, specifically “more” water quality, expressed in terms of how temperatures in the creek affected levels of oxygen and nitrate concentration. The class developed two sets of surveys representing two levels of water quality changes to test for scope sensitivity, where respondents theoretically should be willing to pay more for a higher amount of the good. The survey incorporated maps of the watershed to explain how interventions would work. The classroom contingent valuation project in Boulatoff and Boyer (2010) focused on a wind farm project in upstate New York. The use of a willingness-to-accept approach posed as a negative willingness-to-pay question more readily accommodated responses from people opposed to the project. Concept and survey development occurred primarily among class participants, who gained skills in collaboration and communication. In Henderson (2016), students researched proposals for the good to be valued, first on an individual basis, narrowing the choices at the group level with final selection at the class level, where students chose a program to reduce deer-vehicle collisions in rural Maryland. The project continued with numerous collaborative activities, and valuation results were presented to the county commissioner with informational packets, allowing students perspective on the policy-making side of their research. Finally, Cheo (2006) intentionally sought to foster “civic-mindedness” in a choice experiment on mental health programs for special needs elementary-aged school children in Singapore. Students had extensive interactions with family and friends including those with special needs, school administrators and random members of the public interviewed in the course of survey development and administration. At the end of the course, students reported that they improved their ability to relate to those who face crises and offer greater understanding.

Table 2. Stated Preference Class Projects

Source	Year	Students	Class Type	Delivery	Survey Dev. weeks	IRB?
Andrews (2001)	2000	21	general	mail	3	no
Cheo (2006)	2001	49	general	in-person	?	no
Boulatoff and Boyer (2010)	2006	11	seminar	mail	?	no
Henderson (2016)	2016	12	capstone	mail	4	yes

Table 2 maps out basic characteristics of these four in-class SP experiments. As the table shows, a wide range of class sizes can be accommodated. In a formal exercise, the class may seek approval of the survey exercise from the institution's Internal Review Board (IRB), a path more appropriate perhaps for a specialized, or capstone, course, even engaging students in the activity before the start of the semester to lay groundwork. At the other extreme is an informal class activity where the instructor simply asks students during a class to reveal their WTP regarding a nonuse good.[2]

Among variations is mode of survey delivery. Each technique has its pros and cons. Mail surveys have the advantage of being low-cost, even with the expected 20% response rate (Henderson), but require turnaround time and appropriate sampling frame.[3] In-person surveys have been considered the "gold standard" (Arrow et al., 1993) and puts students face-to-face with interviewees for more immediate formal and informal feedback, as targeted by Cheo. In recent years, more studies are comparing the results of in-person to web-based surveys and finding comparable results (Marta-Pedroso et al., 2007; Lindhjem and Navrud, 2011; Menegaki et al., 2016). The web-based surveys introduce their own design challenges where the roll-out of information is not in real-time control of the interviewer. Validation, clarification and debriefing components of the survey may be modified and adapted for this approach (Gao et al., 2016). Privacy policies specific to online modes is also a consideration. In addition, such an approach would miss the opportunity for students to interact immediately with others in their community whereby a dialogue actively develops. Uneven internet access across the general population raises equity concerns and may introduce another form of bias. However, web-based surveys will most likely grow in prominence in classroom projects.

[2]While many instructors have undoubtedly used this approach, thanks goes to Peter Berck for putting this out there in his inimitable style.
[3]Henderson, Andrews and Boulatoff and Boyer experienced 21%, 28% and 31% response rates, respectively.

https://cbe.miis.edu/joce/vol8/iss1/1
DOI: 10.15351/2373-8456.1133

3. CLASSROOM EXPERIMENT

3.1 San Francisco Bay and Eelgrass

On April 28, 2019, the Mission Blue organization, founded by the famed oceanographer, Dr. Sylvia Earle, designated San Francisco Bay ("the Bay") a "Hope Spot" in recognition of the Bay's importance to marine biodiversity (Mission Blue, 2019). It is the first Hope Spot located in an urban area, increasing the complexity of identifying and measuring the social and ecological values placed on this ecosystem. The Audubon Society identifies the importance of the Bay's seagrass, *Zostera marina*, as a "foundation" (Audubon California, p. 4) for its food web, contributing to herring biomass and spawning,[4] and supporting thousands of migratory and resident bird species for food and habitat. Its extent has varied over time, with an estimated 2628 acres in 2003, 3706 acres in 2009 and 2790 acres in 2014 (Merkel & Associates, Inc., 2015), with Richardson Bay in Tiburon and Pt. Molate in San Pablo Bay as subareas of the Bay with the largest beds. Conditions affecting eelgrass growth include currents, sediments, temperature, light availability, dredging and boat activity, turbidity and marine species populations linked to predation on eelgrass. In recent years, a main problem has been dredging and "anchoring out" of boats where anchor lines have damaged an estimated 30% of eelgrass beds where these vessels were distributed (Merkel & Associates, Inc., p. 9). The EOS Center has undertaken restoration and monitoring efforts, constructing oyster shell reefs, living shorelines and direct plantings since 2012 (Boyer at al., 2017). A core sample test showed that San Francisco Bay eelgrass beds add 0.024 gC/cm^2 per year as compared to non-eelgrass beds (Schile-Beers and Megonigal, 2017) which translates to an additional 1.07 tC/acre. In recognition of its high potential for carbon storage, the Smithsonian Environmental Research Center and the Audubon Society initiated a Voluntary Carbon Standard calculation for eelgrass beds in Richardson Bay, estimating that 1801.1 tons of carbon could be sequestered in Richardson Bay if restoration efforts reached their potential level of 750 additional hectares of eelgrass (Audubon California). Using an estimate of $520/acre/year based on calculations from Cole and Moksnes applied to the acreage range found by Merkel & Associates, Inc., they estimate that the Bay's eelgrass represent $1.4-$1.9 million/year in benefits, depending on the estimated range of acreage. The report as well as other studies also state that restoration projects to date have had limited success due to unpredictable changes in water quality (Audubon California; Börger et al.).

[4] Herring is the last commercial fishery in existence in the San Francisco Bay.

3.2 Course Integration

Environmental Economics (Econ 550/850) is an elective course at San Francisco State University, with intermediate economics as a prerequisite. The class meets once per week for three hours each, which worked to the project's advantage for the field trip and brainstorming sessions described below. The course follows a standard introductory environmental economics class: description and characteristics of environmental goods through an economics lens, benefit-cost analysis, command-and-control versus market-based mechanisms in regulation and policy, discounting, and revealed and stated preference valuation methods. The stated preference methods focused on contingent valuation (CV) where learning objectives were to understand the process and analysis of meaningful willingness-to-pay estimates which environmental policymakers could use as social values. Learning objectives also included strengthened oral and written communication skills through the collaborative process of survey development and administration, final paper assignments and oral presentations.

Integrating the experiment into the curriculum started with the first day of class when the instructor briefly outlined the project during syllabus review. The prospect of taking on a CV project can create anxiety among students over working in teams and time commitment. Establishing the scope of the project early eases concerns somewhat. Particularly important for the Fall 2019 class was setting the date of the field trip and coordinating with the EOS Center. Students' introduction to valuation also occurred the first day of class with an in-class activity grouping students to discuss willingness-to-pay for different environmental goods and then compare their values to those from the actual studies.

The next engagement occurred when stated preference arose in the course, in this case, after modules on goods, externalities and revealed preference. The lecture itself is kept to a minimum to save class time for learning-by-doing. The overview lecture covers motivation, case examples (e.g. Kakadu, Exxon Valdez), basic theoretical underpinnings, survey components, potential sources of bias arising from surveys in general and SP surveys in particular, and WTP estimation.[5] The format charges students with choosing the subject of study, elicitation format, overall survey instrument and sample population, with basic requirements set by the

[5]Cheo (p. 84) advocates for placing the survey bias issues at the end rather than beginning of a CV curriculum as it predisposes the students to focus disproportionately on the method's challenges in the field.

DOI: 10.15351/2373-8456.1133

instructor. Table 3 lists these class sizes and choices over four years of the class.

Table 3. Contingent Valuation Class Projects 2016-2019

Project	Year	Students	Sample size	Elicitation method	Calculation method	WTP estimate
Protected area	2016	14	72	open, SB	weighted avg.	$70
Living roof	2017	7	36	DB	Turnbull	$28-$44
Greenhouse benches	2018	24	88	DB	weighted avg.	$24.68
Eelgrass restoration	2019	28	136	open, SB, DB	average, discrete choice	$42.81

3.3 Selection of Good

The Fall 2019 class had a total of 27 undergraduates and one masters student. Their topics were restricted only to some environmental good related to the Bay. The field trip was scheduled to coincide as soon as possible after the SP overview lecture. The class (100% participation) met on location with scientists for a tour and presentations by four scientists on the ecosystem of the Bay, including eelgrass. To conclude, students met in a conference hall to select an environmental good represented in EOS Center's research and draft a survey. Suggestions included otters, harbor porpoises, fisheries, carbon sequestration in soil up the Sacramento River and eelgrass restoration, among others. The students had had the most in-depth discussions with scientists at the outdoor eelgrass tank which probably led to an eelgrass restoration project prevailing in the final majority vote.

3.4 Survey Development

Immediately after good selection, survey development commenced by splitting the survey into six parts, each with a team of students assigned to its drafting, with facilitated communication among groups to make the survey consistent throughout. The six sections were 1) introduction to set up context of the study, 2) detailed description of the good to be valued, 3) framework for providing the good, 4) payment vehicle as well as the elicitation format, 5) debriefing questions, and 6) demographic characteristics. While the entire survey is a holistic process, the most interdependent sections are good description and provision. For the logistics of combining each group's piece into a single document, an appointed member of each group emailed their contribution to the instructor, who collated the sections into one draft posted to the class website.

Below is described how each survey component evolved between pretest and final survey versions. Students decided with concurrence of instructor that the target population to be sampled would be California residents over the age of 18. Each student independently conducted four pretest and five final survey interviews. On handing in the pretests, students discussed their observations and revised the survey accordingly. If edits extended beyond a few words, the team corresponding to that section sent revisions to the instructor to paste into the final version, which was then made available online for students to download. To grade, the instructor checked hard copies of the survey and reviewed against data entries in the Excel sheet housed in the SFSU Box account accessible to all students. Since surveys were short and only nine total for each student, grading went quickly. See Appendix for a final survey version.

3.5 Survey Components

3.5.1 Survey Introduction

The introduction section included instructions to the student to verify that the respondent fit the intended sample population, with a place to record the student's name, date of interview and code unique to student and interview, followed by an introductory statement identifying the interviewer as a SFSU student. A narrative created context for eelgrass' ecosystemic functions by presenting two attitudinal questions on water quality and climate change mitigation, with responses recorded on a Likert scale of 1-5 (Table 4). This section performed satisfactorily, with no changes between pretest and final versions.

DOI: 10.15351/2373-8456.1133

Table 4. Responses to Environmental Perspective Questions (n=134)

How concerned are you about climate change issues, on a scale of 1 to 5 with 1 being not at all concerned and 5 being very concerned.	
1 (not very)	1.49%
2	9.70%
3	20.90%
4	44.03%
5 (very)	23.88%
How do you rate the water quality in the San Francisco Bay, on a scale of 1 to 5 with 1 being poor and 5 being very good?	
1 (poor)	7.46%
2	19.40%
3	41.79%
4	20.15%
5 (very good)	11.19%

3.5.2 Description of Good and Provision

A clear description of the good to be valued and its provision were the most challenging parts of the survey design, relying most heavily on collaboration among students and scientists. Both these components are mutually supported, and collaboration in developing them was iterative. The instructor facilitated communication between the two designated groups for this section although all groups participated in discussion. The link between eelgrass and ecosystem benefits needed to be explicitly but briefly summarized as part of elaborating a credible god and program to be valued (Johnston et al., 2017a, p. 327). Scientists discussed restoration efforts in detail during the tour, such as direct planting and construction of floating platforms and man-made reefs, with success dependent on environmental variables beyond the biologists' control. During the survey development session, a biologist joined the meeting for overall questions and to exchange ideas about extent of restoration approaches. After some consultation, scientists suggested a goal of 200 acres over a 10-year period rather than the 900 acres proposed by students, even though some reports state the potential in the Bay to be on the order of 750 hectares, or about 1850 acres over an unspecified time period, just in Richardson Bay (Audubon California, p. 9). This was a crucial contribution, in line with recommendations in Börger et al. Allocating money into a fund exclusively for the EOS Center to carry out restoration constituted good provision.

These sections experienced the most editing between pretest and final versions in both verbal exposition and addition of supplemental aids, as in Henderson (p. 249), requiring further class collaboration and negotiation. Börger et al. (p. 143) suggest the use of maps and other visuals created in coordination with natural scientists to communicate with the target audience as another point of interdisciplinary project development. The pretest version included only a photo of "crop circle" damage, the circular pattern of carving away at eelgrass beds as an anchored boat rotates around its mooring with the currents and tides (Figure A.2.2 in Appendix). Students were assigned or volunteered to find better maps and photos. The final version added a photo of the eelgrass itself (Figure A.2.1), an image of eelgrass coverage changes over three points in time (Figure A.2.3), and a map of the Bay edited by a student to show where restoration projects would take place (Figures A.2.4). Students in this group made edits and the instructor added verbiage to relate the extra carbon sequestration provided by the project to avoided gasoline consumption, based on calculations in the Audubon report (Audubon California). Students later reported that these changes were major improvements in administering the final survey.

3.5.3 Payment Vehicle and Elicitation Format

Responsibility for the payment vehicle and elicitation format were combined into one group of students, since these two survey components run closely together in exposition. Students were coached that the survey would have open-ended and closed-ended WTP questions. The open-ended question has the advantage of yielding data which students can manipulate with basic statistical knowledge. The closed-ended responses allowed for bid pattern tables and basic comparisons as initial bids increase as well as econometric estimation using the dichotomous choice model for the masters student. Students chose to frame the payment vehicle as a referendum on a one-time tax. Hanemann (1985) and Richard Carson first proposed the double-bounded (DB) method that includes follow-up bids depending on if the respondent answered yes or no to the initial bid, with a lower follow-up option for those that said no and a higher option for those that said yes. The WTP measures in dichotomous, closed-ended approaches are supported theoretically by random utility models and estimated with parametric and nonparametric methods. The DB model offers precision gains over the single-bounded approach but may be susceptible to starting point bias, where the probability of saying yes to the second bid is systematically different than if the respondent was initially asked the value of the second bid (Alberini et al., 1997; Hanemann et al., 1991; Flachaire and Hollard, 2006; Carson and Hanemann, 2005). The closed-ended bid section was then followed by the open-ended question asking the respondent the maximum amount they would be willing to pay for the good, which may introduce starting point bias in relation to the prior closed-ended question.

Regarding choice of initial bid points, students chose initial and follow-up values during the brainstorming session with the instructor at a whiteboard, after the group assigned to this task fashioned the elicitation question format. Thus, bid values most likely reflect students' own WTP expectations. Students also agreed as a class with the group's choice of a one-time payment of a lump-sum tax on state income tax returns as the payment vehicle. The ranges were set in three versions of the survey, with $10, $15, $5 for the low spectrum, $20, $30, $15 as the middle and $50, $75, and $40 as the highest set of values. The question read: *"We are asking people about a ballot measure to fund this program. The ballot measure would be a one-time tax for all California individuals into a fund for the Estuary Ocean Science Center to be used solely for the purpose of planting, maintaining and monitoring 20 acres/year of eelgrass beds for ten years in the Bay to achieve 200 extra acres by 2030. If the measure is on the November 8 ballot, and the one-time tax would be an extra* $*X fee when you pay your taxes in 2020, would you vote for this program?"* where $X would be $10, $20 or $50. The open-ended version read: *What would be the maximum that you would pay to the Estuary Ocean Science Center for them to plant the eelgrass bedding habitats in the Bay area for a one-time cost fee through taxes?* For the purposes of this study, no additional treatment was applied to adjust the right-hand tail of the distribution. The sample was skewed to a younger population in lower income brackets, making imposition of an upper bound constraint less of a concern.

3.5.4 Debriefing

After the closed- and open-ended WTP questions, the surveys followed with typical debriefing questions designed for reliability checks. For example, debriefing questions allow researchers to eliminate protest responses which are inherent consequences of contingent valuation surveys. Students relatively easily grasp the idea of the "protest vote," which encourages them to consider alternative perspectives towards environmental goods and reactions to the program.[6] For those who respond with a positive value, debriefing questions can identify issues with scope of the good being valued: e.g. is the person valuing a general

[6]Someone who says they would not value the good at all may be registering dissatisfaction with the way the good is presented or provided, rather than reflect an actual zero valuation. In this case, the zero value does not fit the theoretical definition of WTP, and common practice is to drop these zero values once identified.

environmental cause, for example, rather than eelgrass restoration as defined?

Table 5 reports reasons for choosing a positive value for any WTP question for the full dataset. For those who say they are contributing to a "good cause," this study chose to leave in these responses in agreement with Carson and Hanemann that these are legitimate viewpoints in placing WTP on a good.

Table 6 reports on those who declined to offer any amount towards the project in either the open- or closed-ended questions. Answers a) and b) are consistent with a zero value placed on the good, while the rest reflect a rejection of the program itself. These responses (n=8) are removed as protest votes for the final WTP valuations.

Table 5. Reason for positive WTP response, N=134

Response		N
a.	This program is worth this amount to me	18
b.	The eel grass beds are worth this much to me to protect	16
c.	To contribute towards a good cause	43
d.	We have a responsibility to protect the ocean	44
e.	Other reasons	3
NA		9

Table 6. Reason for zero WTP responses, N=134

Response		N
a.	Eel grass bed rehabilitation is not worth anything to me	1
b.	I can't afford to pay at this time	1
c.	I don't think protecting eel grass beds is going to help	3
d.	I don't think this program is going to rehabilitate eel grass	0
e.	I am opposed to government programs	2
f.	It is unfair to ask me to pay for this program	1
g.	I do not believe in more taxes so I do not want to pay them	2
NA		124

After the pretest surveys, some students questioned the limits of the protest concept to only zero WTP responses and discussed extending the idea to explaining why a respondent claimed the amount they were willing to pay and *not more* than that amount. In the spirit of experimentation, we added a follow-up question (PROTEST1) to anyone offering a positive WTP value. Results are shown in Table 7. Responses a) and b) are consistent with the valuation model. However, a number of responses revealed respondents hedging their bets or showing doubt about the effectiveness of the program or payment vehicle. This speaks to uncertainty masquerading as certainty as it maybe presented in stated preference studies (Bӧrger et al., p.148). Aside from hypothetical bias addressed by an uncertainty adjustment (e.g. Akter et al., 2008), respondents perceived degrees of uncertainty inherent in the provision of the good and modified their WTP responses as such. Eelgrass restoration through planting beds is difficult to establish, as noted above. Other respondents were not completely comfortable with the payment vehicle or government programs as the way to supply the good, in which case, they also modified their WTP responses as a type of “protest” or uncertainty correction.

Table 7. Reason for maximum positive WTP response, N=134

	Response	N
a.	Eelgrass bed rehabilitation is not worth more to me	20
b.	I can’t afford to pay more at this time	60
c.	I feel like I have to contribute, but I don’t think protecting eelgrass beds is effectively going to help	16
d.	I feel like I have to contribute, but I don’t think this program is going to effectively rehabilitate eelgrass	6
e.	I am usually opposed to government programs	8
f.	I don’t believe in taxes so I don’t want to pay a higher amount	5
g.	Other reasons	5
NA		14

3.5.5 Demographics

Demographic and socioeconomic characteristics can also explain WTP variations but seemed the least interdisciplinary part of the survey design, mostly informed by economic theory and practice. Students agreed on income, gender and whether respondents lived or originated in the Bay Area as factors potentially affecting WTP. In addition to a greater sense of connection afforded by proximity to the Bay, environmentalism is popular in the Bay Area, conceivably leading to higher mean WTP values than other areas of the state. The likelihood of visiting the Bay Area in the next five years was included for similar reasons. In this class, the demographic section remained unchanged between pretest and final versions. Data by total and survey version and full sample is summarized in Table 8.

The exercise resulted in 134 final survey observations. Other than requiring that respondents be California residents 18 years or older, students were free to choose who they interviewed to reduce time and complexity and stay focused on the overall process of valuation research design. Most students interviewed persons from their circle of family, friends, or university community. Thus, the results that follow, while informative, should be interpreted in this light.

4. RESULTS

The empirical analysis consisted of descriptive statistics, bid pattern analysis, a WTP estimation based on open-ended responses, and econometric estimation based on closed-ended responses, reported here and developed by the instructor for illustration. Furthermore, seven students chose for their separate paper and oral presentation assignment topics related to EOS Center research, including the eelgrass project itself, environmental justice and water quality. Although EOS Center scientists were invited to attend oral presentation sessions pertaining to the project, this was not possible, and only written work was shared with them.

Table 8: Demographic Data Summary by Survey Version

Variable	V1	V2	V3	Full
No. of respondents	46	50	38	134
Average age	28.33	27.44	33.61	29.49
Female	50.00%	42.00%	34.21%	42.54%
Male	50.00%	58.00%	65.79%	57.46%
Not married	80.43%	80.00%	63.16%	75.37%
Bay Area Origin	45.65%	34.00%	31.58%	37.31%
Bay Area Resident	80.43%	86.00%	81.58%	82.84%
Education levels:				
High School Diploma	13.04%	10.00%	5.26%	9.70%
Some college experience	43.48%	56.00%	42.11%	47.76%
Bachelor's Degree	30.43%	30.00%	39.47%	32.84%
Master's Degree	8.70%	4.00%	7.89%	6.72%
PhD	4.35%	0.00%	5.26%	2.99%
Income levels:				
≤ $25,000	54.35%	50.00%	28.95%	45.52%
$25,000 - $50,000	17.39%	30.00%	21.05%	23.13%
$50,000- $100,000	19.57%	14.00%	36.84%	22.39%
$100,001 and above	8.70%	6.00%	13.16%	8.96%
Plans to visit BA	95.65%	92.00%	94.59%	93.98%

Table 9: Summary Statistics for OPENWTP

	Full sample	No protest
Mean	$32.46	$34.52
Median	$30.00	$30.00
SD	$24.51	$23.82
N	134	126

4.1 Statistical Calculations

The data analysis for the entire class was split into seven statistical assignments, or "activities."[7] Starting with the simplest of measures, we find that the average for the open-ended WTP question was $32.46 (Table 9). Dropping the eight protest votes, i.e. those that recorded any c-h responses in Q9 PROTEST2, the average is $34.52, slightly higher than the full sample, whereas the median (and minimum and maximum) is the same in both samples. Using the Wilcoxon rank sum test, we cannot reject the null that the difference between the averages is zero, while a normal q-q plot is right-skewed, i.e. there is a higher concentration of data at higher quantiles than would be expected in a normal distribution.

A "sanity check" of whether WTP responses comply with the Law of Demand is given in the pattern of yes and no's across the three survey versions, called a "bid pattern" (Table 10). We expect to see the percentage of yes responses to decrease as the initial bid value increases. This is the case as we observe the decrease in yes-yes pattern from version 1 to version 3 (using sample without protest votes). Conversely, the number of no's increases for the yes-no, no-yes, and no-no respondents as the bid values are scaled up across versions. The bids themselves have minimal overlap between versions to limit anchoring bias (Hanemann et al., 1991). The patterns in responses are also some reassurance that anchoring bias within the dichotomous choice model will not be a major issue.[8]

Table 10: Bid Pattern, N=126

Version	n	Yes-Yes	Yes-No	No-Yes	No-No
V1 ($10,$15,$5)	43	83.72%	11.63%	0.00%	4.65%
V2($20, $30, $15)	47	57.45%	27.66%	6.38%	8.51%
V3 ($50, $75, $40)	36	19.44%	27.78%	11.11%	41.67%

[7]To complete this assignment, each student downloaded an Excel spreadsheet from a Box folder. The spreadsheet embedded many of the required Excel commands (e.g. how to group data by age, gender or income levels, t-tests)

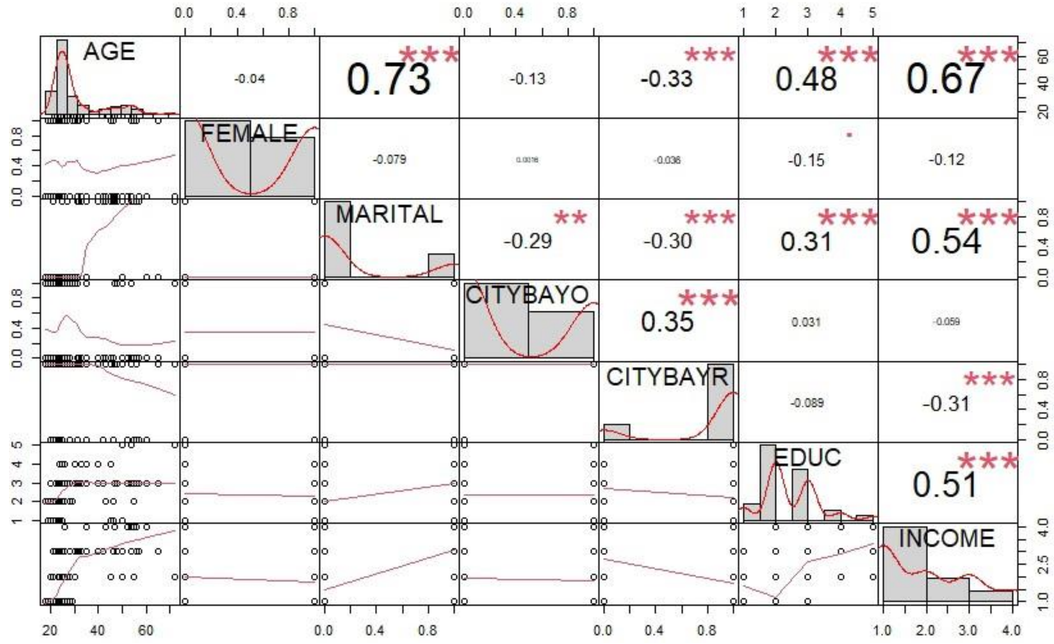
[8]For example, there is a modest amount saying both yes and no to $15 after initially being asked $20 for version 2, still a modest percentage saying no to $15 after the initial bid of $10, along with the large percentage in version 1 saying yes to $15 after the initial bid of $10.

Figure 1 details the correlations among variables for all observations except VISIT, dropped due to lack of variation.[9] In the upper triangle, correlation coefficients are shown with significance levels over 10% indicated by asterisks. We see that AGE and MARITAL are highly correlated, probably as students are asking their parents to participate in the survey. AGE is also highly correlated with EDUC and INCOME. The diagonal elements of the graph show the distribution, with values given along the horizontal axes. The lower triangle elements show bivariate data distribution with a fitted line, with row values given on the vertical axes.

Further activities included sorting the data into groups for hypothesis testing. Splitting the sample into the two highest and two lowest income brackets used to characterize income levels, we found that the "high" income group had a higher average WTP ($38.08) from the open-ended responses than the "low" income group ($32.92). However, the t-statistic of -1.12 was not significant for either the one- or two-tailed test. Likewise, there was no statistical difference detectable between those originally from the Bay Area and those who were not (t = 0.71). Nonresidents of the Bay Area surprisingly had higher mean WTP than Bay Area residents, $35.69 v. $32.60, significant at the 10% level (t = 1.67). However, the highly unbalanced distribution of 83% residents versus 17% nonresidents reduces the efficacy of this variable in our analysis.

Figure 1. Correlations coefficients and data distribution

p-values: "***" < 0.001, "**" = 0.001, "*" = 0.05, "." = 0.1



[9]Students provided a simple pairwise correlation table.

4.2 Regression analysis

The single-bounded dichotomous choice model uses a logit regression where the yes-no response, coded as 0-1, is regressed on initial bid value and a set of other explanatory variables. The double-bounded choice model builds from the four possible bid patterns with initial and follow-up bids as arguments. Using notation from Hanemann et al. (1991), the four probabilities are:

$$\pi^{yy}(B_i, B_i^u) = 1 - G(B_i^u; Z, \theta) \quad (1)$$
$$\pi^{yn}(B_i, B_i^u) = G(B_i^u; Z, \theta) - G(B_i; Z, \theta) \quad (2)$$
$$\pi^{ny}(B_i, B_i^d) = G(B_i; Z, \theta) - G(B_i^d; Z, \theta) \quad (3)$$
$$\pi^{nn}(B_i, B_i^d) = G(B_i^d; Z, \theta) \quad (4)$$

where π is the probability of the bid pattern response indicated in the superscript, $G(\bullet)$ is the logistic cumulative density function, with initial bid amount B_i and follow-up bid, either B_d for a no-response or B_u for a yes-response for respondent i, Z is the vector of demographic and attitudinal variables and θ is the parameter vector. The log-likelihood function is expressed as:

$$\begin{aligned} \ln L(\theta) \quad = \quad & \{ d_i^{yy} \ln \pi^{yy}(B_i, B_i^u) \\ + \quad & d_i^{yn} \ln \pi^{yn}(B_i, B_i^u) \\ + \quad & d_i^{ny} \ln \pi^{ny}(B_i, B_i^d) \\ + \quad & d_i^{nn} \ln \pi^{nn}(B_i, B_i^d) \} \end{aligned} \quad (5)$$

where d_i^{yy}, d_i^{yn}, d_i^{ny}, and d_i^{nn}, are indicator variables taking a 0-1 value depending on the bid pattern for each individual i. The maximum likelihood estimator solves for θ to satisfy $\partial \ln L(\hat{\theta})/\partial\theta) = 0$.

The mean WTP in SB and DB is the ratio of the linear sum of coefficients multiplied by variables evaluated at the mean to the bid coefficient (Carson and Hanemann):

$$\overline{WTP} \quad = \quad \frac{1}{\hat{\beta}_{bid}}(\hat{\alpha} + \hat{\beta}_Z' \bar{Z}) \quad (6)$$

where $\hat{\beta}_{bid}$, $\hat{\alpha}$ and $\hat{\beta}_Z'$ are the estimated coefficients on bid, constant and Z-variables, respectively. The R add-on statistical package DCchoice (Nakatani et al., 2016; Aizaki et al., 2014) estimates both the single-bounded (SB) and double-bounded (DB) models. Our preferred model drops variables for age, marital status, education level to reduce multicollinearity, and indicators for Bay Area residency and plans to visit the Bay Area due to low variation.

Table 11 reports results. Across specifications, the bid variable is strongly significant, where the odds of saying yes to the bid decreases as the size of the bid increases, as expected. This holds true when the bid variable is the single regressor (Models SB1 and DB1) and when included with the other variables (SB2 and DB2). In both the SB and DB versions, women are more likely to respond yes to a given bid, though the effect is statistically significant only in the DB version. Higher income levels also have a positive influence but are significant only in the DB model. Having greater concern for climate change issues raises a person's willingness to pay for the program, as does having a poorer assessment of existing water quality, though the latter is statistically significant in the SB model only. Originating from the Bay Area did not have any significant effect on WTP.

As expected, mean WTP is lower and has narrower confidence intervals in the DB models as compared to the SB versions ($42.81 versus $47.61). Truncating at the maximum bid[10] of $75.00 reduces the mean WTP in all cases but more substantially in the SB models. Confidence intervals on means and medians are calculated using the Krinsky- Robb method. In both the SB and DB versions, adding covariates reduces the Akaike Information Criteria (AIC) score, justifying adding these variables to the model, and all likelihood ratio statistics are significant at better than the 1% level. The fourth and seventh columns report marginal probabilities, where calculations were made by holding covariates at their means and using the estimated mean WTP reported in the table.

[10]Truncating at a maximum amount attempts to avoid the "fat right-tail" problem that occurs when the upper bound of a cumulative distribution function is not specified and thus overestimates the mean WTP (Carson and Hanemann, p.859, 886).

DOI: 10.15351/2373-8456.1133

Table 11: Single and Double-Bounded Regression Results, n=126

Model:	SB1	SB2	Marginal prob.	DB1	DB2	Marginal prob.
Variable	Coefficient (SE)			Coefficient (SE)		
Intercept	3.342***	2.556	–	2.561***	-1.131	–
	(0.553)	(1.783)		(0.310)	(1.396)	
Bid	-0.070***	-0.091***	–	-0.061***	-0.072***	–
	(0.014)	(0.020)		(0.008)	(0.009)	
Female		0.675	0.169		1.136**	0.277
		(0.609)			(0.439)	
Income		0.476	0.119		0.517*	0.129
		(0.311)			(0.229)	
Concern		0.681*	0.170		0.747**	0.187
		(0.285)			(0.243)	
Water quality		-0.726*	-0.081		-0.071	-0.018
		(0.304)			(0.206)	
Bay Area origin		0.305	0.076		-0.011	-0.003
		(0.599)			(0.421)	
Mean WTP	$48.45	$47.61		$43.35	$42.81	
Conf. Interval	$40.86-$62.15	$41.68-$59.57		$37.40-$51.79	$37.58-$49.80	
Mean WTP trunc.	$39.49	$41.16		$41.26	$41.56	
Conf. Interval	$35.89-$42.44	$36.83-$44.16		$36.22-$46.81	$36.79-$46.87	
Median	$47.95	$47.46		$42.13	$42.15	
Conf. Interval	$40.61-$60.40	$40.61-$59.14		$36.00-$50.09	$36.72-$49.05	
Log-likelihood	-53.04	-41.541		-134.57	-120.964	
AIC	110.08	97.082		273.14	255.93	

Significance codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Using the most conservative figure of mean WTP truncated at the maximum bid, $41.56 (DB2), and a figure of 13 million California households assuming one tax return per household (U.S. Census Bureau, 2019), total WTP in California for the restoration project would be $540,280,000. Mean WTP is similar to Wallmo and Lew and substantially higher than the Hepu study. This is notable even when the sample is biased towards relatively low income groups. A per acre basis of comparing across studies may not be valid because the nature of what exactly is being valued can differ and is not necessarily an “acre of eelgrass bed.” A future extension could include scope sensitivity tests varying the size of the “good,” as well as a more representative sample.

To depict survey results further, Figures 2 and 3 show the logistic cumulative distribution functions for the single-bounded and double-bounded models, for females versus males in the highest and lowest income brackets. In this sample, males in the lowest bracket have the lowest willingness to pay, followed by females in the lowest bracket, males in the highest, and females in the highest bracket.

Figure 2. Estimated single-bounded choice probabilities, by gender and income

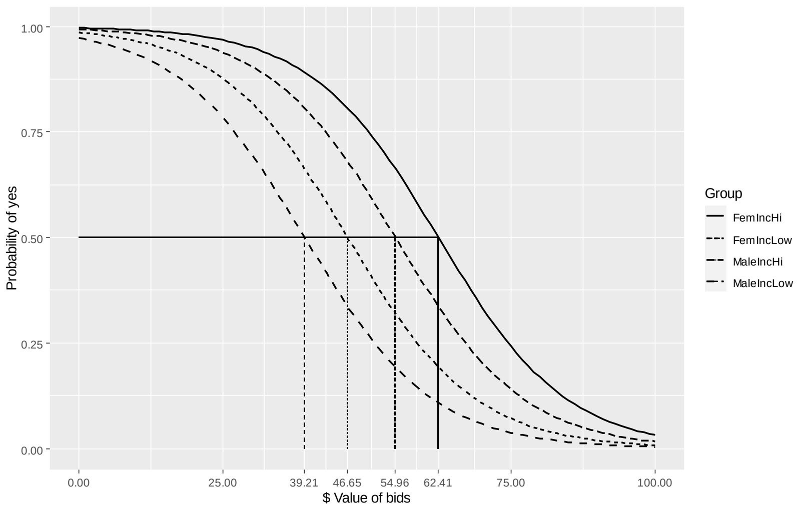
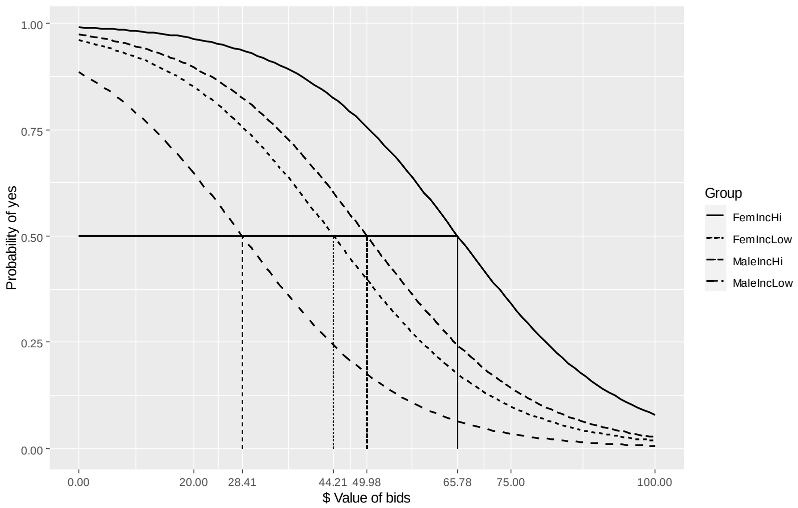


Figure 3. Estimated double-bounded choice probabilities, by gender and income



5. LEARNING OUTCOMES AND STUDENT FEEDBACK

Student feedback for this particular project was organized into: 1) pre- and post- exercise evaluations aimed at providing information on how well the exercise served in advancing educational goals set out by the economics department, and 2) a confidential feedback form regarding strengths and weaknesses, completed at the end of the project. In addition, students respond to university-sponsored teaching and course evaluation forms at the end of each semester. This feedback is discussed below.

5.1 Pre- and post-evaluations

For the first approach, students were asked to self-assess their comfort level on a scale of 1 (least) to 5 (most) with the two department's program objectives that pertained to this activity, with a set for the undergraduate students. The first related goal states: *In the program, students will master the ability to collect, process, interpret, analyze and draw conclusions from economic information and economic data using appropriate quantitative methods.* The second goal states: *In the program, students will develop and expand on skills necessary to effectively communicate economic ideas both orally and in writing to a wide audience.* For the first, undergraduates reported an average pre-project comfort level of 3.21 and post-project of 4, where the one-tailed *t*-test has *p*-value significant at better than the 1% level. For the second, averages pre- and post-project were 3.29 and 3.8, respectively, with a one-tailed *t*-test *p*-value significant at the 5% level.[11]

5.2 Student comments

The interdisciplinary nature of the exercise came through as a strength in confidential comments. Student comments included "explaining the benefits was well done; pictures and maps helped;" "the field trip was highly informative and enhanced survey administration;" and "framing the problem was strong." A number also noted the collaborative portions of the process as easy and smooth and "made the project doable." The tradeoff of informal but quick sampling and survey administration was noted by students as the main weakness. Given the degree of freedom in sampling, students most frequently interviewed persons known to them, such as family and friends. Therefore, the sample, as noted in the results section, was biased towards a younger population than the average target population of Californians over 18 years old. Suggestions included making the target population only SFSU students or only residents of the Bay Area.

In the university-sponsored evaluations, students mentioned the contingency valuation project most often when prompted for the "most

---

[11] The one masters student filled out a separate evaluation. The first graduate-level goal which this course supports is: *Students will learn practical skills in collecting, processing, interpreting and analyzing economic data with appropriate statistical and econometric techniques.* The second is: *Students will be able to employ economic reasoning in analyzing real world economic problems and effectively communicate their knowledge and findings both orally and in written formats.* For both goals, the student reported an increase from 3 to 5 on the scale.

significant ideas, concepts, and skills gained" from this course, citing research and analytical skills, "learning how to think about how we come up with a value for the environment," and "the idea that anything without a price can be valuated using practices such as valuation surveys."

5.3 Improvements for future

The opportunity to hold a field trip to a scientific center to meet face-to-face with natural scientists was a key point in introducing interdisciplinarity into the economics classroom. The framing of the project and the description of the good relied heavily on this exchange. It is worthwhile to meet natural scientists in their own research labs to view the subject of their studies. However, other possible options would be guest appearances in the classroom or online video sessions.

Given this particular framework for integrating the marine sciences into the project, several ways to improve the course can be recommended. First is to support even further the collaborative process in the survey design phase by organizing students into groups earlier in process to discuss separate survey components in greater detail and allow a full 1-1.5 hours for the collaboration in the actual survey draft session. Once the draft is assembled, it would be useful to allow more time than was permitted in this experiment for students to practice administering the survey and handling the maps and photos at the appropriate points in the survey. Finally, more effort can be given to establishing a representative sample of a target population, especially if some groundwork could be established prior to the semester to permit, for example, a mail survey as in Henderson or Andrews, where samples were purchased. Online surveys could also be considered, with attention to best practice and online security precautions. More formalized approaches could rely on internal review board approval. Finally, cross-communication of the final results with the marine scientists involved in project development could provide shared insight and feedback for further policy development around eelgrass conservation and restoration efforts.

6. CONCLUSION

This paper proposes that undergraduate economics education incorporate more studies of marine ecosystems and the blue economy to prepare students to address climate change policy and that this education should lay the groundwork for engaging students in interdisciplinary research. The stated preference framework lends itself to interdisciplinary, collaborative research and can be brought into the classroom in a range of ways to fit the capacity and constraints of a one-semester course. Undoubtedly, many other approaches can be created. The focus on eelgrass, being a lesser known species in an environment often remote to the general public, allowed this class experiment to engage with natural scientists in the project design to elucidate ecosystem linkages understandable both to students and the set of survey respondents. The results illustrate both educational opportunities and scope for further stated preference studies of eelgrass as an important climate change mitigator. Students experience a full range of learning outcomes and are generally well-served by the exercise, as is, it is hoped, the broader global community.

REFERENCES

Aizaki, H., Nakatani, T., and Sato, K. (2015). *Stated Preference Methods Using R*. CRC Press, Taylor & Francis Group: Boca Raton, FL.

Akter, S., Bennett, J., and Akhter, S. (2008). Preference uncertainty in contingent valuation. *Ecological Economics*, 67(3):345 – 351.

Alberini, A., Kanninen, B., and Carson, R. (1997). Modeling response incentive effects in dichotomous choice contingent valuation data. *Land Economics*, 73(3):309 –324.

Alcamo, J. and Bennett, E. (2003). *Ecosystems and Human Well-Being: A Framework for Assessment/Millennium Ecosystem Assessment*. Island Press, Washington, DC.

Andrews, T. (2001). A contingent valuation survey of improved water quality in the Brandywine river: An example of applied economics in the classroom. *Pennsylvania Economic Review*, 10(1):1–13.

Arrow, K., Solow, R., Portney, P., Leamer, E., Radner, R., and Schuman, H. (1993). Report of the NOAA panel on contingent valuation. *Federal Register*, 58(10):4601 – 4614.

Audubon California (2018). Eelgrass, herring and waterbirds in San Francisco Bay: Threats and opportunities. Technical report, The Audubon Society, Tiburon, California. Report to the Gordon and Betty Moore Foundation.

Bedulli, C., Lavery, P. S., Harvey, M., Duarte, C. M., and Serrano, O. (2020). Contribution of seagrass blue carbon toward carbon neutral policies in a touristic and environmentally-friendly island. *Frontiers in Marine Science*, 7:1.

Boulatoff, C. and Boyer, C. (2010). Using contingent valuation with undergraduate students to elicit a community's preferences for wind farm development. *Applied Economics Letters*, 17(14):1361–1366.

Börger, T., Böhnke-Henrichs, A., Hattam, C., Piwowarczyk, J., Schasfoort, F., and Austen, M. C. (2018). The role of interdisciplinary collaboration for stated preference methods to value marine environmental goods and ecosystem services. *Estuarine, Coastal and Shelf Science*, 201:140 – 151.

Börger, T. and Piwowarczyk, J. (2016). Assessing non-market benefits of seagrass restoration in the Gulf of Gdańsk. *Journal of Ocean and Coastal Economics*, 3(1):1–28.

Boyer, K., C. Zabin, S. De La Cruz, E. Grosholz, M. Orr, J. Lowe, M. Latta, J. Miller, S. Kiriakopolos, C. Pinnell, D. Kunz, J. Moderan, K. Stockmann, G. Ayala, R. Abbott, and R. Obernolte (2017). San Francisco Bay Living Shorelines: Restoring Eelgrass and Olympia Oysters for Habitat and Shore Protection. In D. M. Bilkovic, M. Mitchell, J. Toft, and M. La Peyre, eds., *Living Shorelines: The Science and Management of Nature-Based Coastal Protection*, chapter 17, CRC Press Marine Science Series.

Carson, R. and Hanemann, M. (2005). Contingent valuation. In Mäler, K. and Vincent, J., eds., *Handbook of Environmental Economics*, chapter 17, pages 822–936. Elsevier B.V.

Cheo, R. (2006). Teaching contingent valuation and promoting civic mindedness in the process. *International Review of Economics Education*, 5(2):81–97.

Colander, D. and McGoldrick, K. (2010). *Educating economists: The Teagle discussion on re-evaluating the undergraduate economics major*. Edward Elgar, Cheltenham, UK.

Cole, S. G. and Moksnes, P.-O. (2016). Valuing multiple eelgrass ecosystem services in Sweden: Fish production and uptake of carbon and nitrogen. *Frontiers in Marine Science*, 2(121):61–78.

Costanza, R., d'Arge, R., de Groot, R., and et al. (1997). The value of the world's ecosystem services and natural capital. *Nature*, 387:253–260.

Duarte, C. M., Kennedy, H., Marbà, N., and Hendriks, I. (2013). Assessing the capacity of seagrass meadows for carbon burial: Current limitations and future strategies. *Ocean & Coastal Management*, 83:32 – 38.

Duarte, C.M., Middelburg, J.J., and Caraco, N. (2005). Major role of marine vegetation on the oceanic carbon cycle. *Biogeosciences*, 2(1):1–8.

Flachaire, E. and Hollard, G. (2006). Controlling starting-point bias in double-bounded contingent valuation surveys. *Land Economics*, 82(1):103–111.

Gao, Z., House, L., and Xie, J. (2016). Online survey data quality and its implication for willingness-to-pay: A cross-country comparison. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, 64(2):199–221.

Goldsmith, A. H. (2018). Interdisciplinary approaches to teaching. https://serc. carleton.edu/48976 (12/3/2020).

Han, Q., Huang, X., Shi, P., and Zhang, J. (2008). Seagrass bed ecosystem service valuation - a case research on Hepu seagrass bed in Guangxi province. *Marine Science Bulletin*, 10(1):87–96.

Hanemann, M. (1984). Welfare evaluations in contingent valuation experiments with discrete responses. *America Journal of Agricultural Economics*, 66(3):332–341.

— (1985). Some issues in continuous- and discrete-response contingent valuation studies. *Northeastern Journal of Agricultural and Resource Economics*, 14(1):5–13.

Hanemann, M., Loomis, J., and Kanninen, B. (1991). Statistical efficiency of double-bounded dichotomous choice contingent valuation. *American Journal of Agricultural Economics*, 73:1255–1263.

Hanley, N., Hynes, S., Patterson, D., and Jobstvogt, N. (2015). Economic valuation of marine and coastal ecosystems: Is it currently fit for purpose? *Journal of Ocean and Coastal Economics*, 2:1–24.

Harvard School of Public Health (2020). Definitions. Available at https://www.hsph.harvard.edu/trec/about-us/definitions/ (11/8/20).

Henderson, A. (2016). Growing by getting their hands dirty: Meaningful research transforms students. *Journal of Economic Education*, 47(3):241-257.

Hoegh-Guldberg, O. (2019). The ocean as a solution to climate change: Five opportunities for action. Technical report, World Resources Institute, Washington, DC.

Johnston, R. J., Boyle, K. J., Adamowicz, W. V., Bennett, J., Brouwer, R., Cameron, T. A., Hanemann, W. M., Hanley, N., Ryan, M., Scarpa, R., Tourangeau, R., and Vossler, C. A. (2017a). Contemporary guidance for stated preference studies. *Journal of the Association of Environmental and Resource Economists*, 4(2):319–405.

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

Johnston, R. J., Schultz, E. T., Segerson, K., Besedin, E. Y., and Ramachandran, M. (2017b). Biophysical causality and environmental preference elicitation: Evaluating the validity of welfare analysis over intermediate outcomes. *American Journal of Agricultural Economics*, 99(1):163–185.

Lew, D. (2015). Willingness to pay for threatened and endangered marine species: a review of the literature and prospects for policy use. *Frontiers in Marine Science*, 2(96):10–28.

Lindhjem, H. and Navrud, S. (2011). Are internet surveys an alternative to face-to-face interviews in contingent valuation? *Ecological Economics*, 70(9):1628–1637.

Maritime Affairs (2020). Call for tenders: Ocean literacy for all. https://ec.europa.eu/maritimeaffairs/press/call-tenders-ocean-literacy-all_en. (Accessed 11/12/2020).

Marta-Pedroso, C., Freitas, H., and Domingos, T. (2007). Testing for the survey mode effect on contingent valuation data quality: A case study of web based versus in-person interviews. *Ecological Economics*, 62(3-4):388–398.

Mehvar, S., Filatova, T., Dastgheib, A., van Steveninck, E., and Ranasinghe, R. (2018). Quantifying economic value of coastal ecosystem services: a review. *Journal of Marine Science and Engineering*, 6(1):5.

Menegaki, A. N., Olsen, S., and Tsagarakis, K. (2016). Towards a common standard – a reporting checklist for web-based stated preference valuation surveys and a critique for mode surveys. *Journal of choice modelling*, 18(C):18–50.

Merkel & Associates, Inc. (2015). San Francisco Bay eelgrass inventory, October 2014. Technical Report #05-024-35, Merkel & Associates, Inc. Submitted to National Marine Fisheries Service, Santa Rosa, CA.

Mission Blue (2019). New Hope Spot in San Francisco Bay highlights need for comprehensive ocean conservation action. https://mission-blue.org/2019/04/new-hope-spot-in-san-francisco-bay-highlights-need-for-comprehensive-ocean-conservation-action/. Accessed 10-September-2020.

Nakatani, T., Aizaki, H., and Sato, K. (2016). Package 'dcchoice': Analyzing dichotomous choice contingent valuation data. Technical report, CRAN Repository.

NSSE (2018). NSSE 2018 – High-impact practices: National survey of student engagement. Technical report, NSSEville State University.

Raheem, N., Talberth, J., Colt, S., Fleishman, E., Swedeen, P., Boyle, K. J., Rudd, M., Lopez, R. D., O'Higgins, T., Willer, C., and Boumans, R. M. (2009). The economic value of coastal systems of California. Technical Report EPA/600/F-09/046, US Environmental Protection Agency.

Schile-Beers, L. M. and Megonigal, J. P. (2017). Blue carbon analysis of eelgrass beds in Richardson Bay, San Francisco Bay, California. Technical report, Audubon California.

U.S. Census Bureau (2019). Quick facts California. https://www.census.gov/quickfacts/CA (Accessed 10/10/2019).

Wallmo, K. and Lew, D. (2015). Public preferences for endangered species recovery: an examination of geospatial scale and non-market values. *Frontiers in Marine Science*, 2:27–33.

Zilberman, D. (1994). Economics and interdisciplinary collaborative efforts. *Journal of Agricultural and Applied Economics*, 26(1):35–42.

APPENDIX

A.1 Final survey (version 1, initial bid = $10)

Interviewer name (your name): ____________________	Interview code: __________	Date:___________

Before the interview: Verify that the person is over 18 and is a resident of California.

Introduction: We are undergraduate students attending SFSU and we're doing a survey regarding a governmental program aimed at improving the water quality and possibly slowing climate change issues within the San Francisco Bay.

Q1. CONCERN How concerned are you about climate change issues, on a scale of 1 to 5 with 1 being not at all concerned and 5 being very concerned. *Circle one answer*

1	2	3	4	5

Q2. WQ How do you rate the water quality in the San Francisco Bay, on a scale of 1 to 5 with 1 being poor and 5 being very good? *Circle one answer*

1	2	3	4	5

The bay has open waterways and natural habitats that stretch farther inland from the ocean. The water is known to be murky and dark because of the increased sediment discharge within it. In recent years there are fewer commercial fishing areas and low levels of carbon storage. In the Bay, there are beds of vegetation called eelgrass which provided multiple benefits to both California residents and Bay Area habitats. They look like this:

SHOW: Page with photos of eelgrass *(file: EELGRASSPhotos)*.

The beds help trap sediment and lessen the waves in the bay that spread the loose sediment around. Eelgrass also provides habitats for animals who use them as spawning surfaces such as the Pacific Herring which is the main product of the Bay Area's last commercial fishery, and they trap carbon dioxide which is a greenhouse gas that causes global warming. These eelgrass beds used to be dotted throughout the bay area but have been slowly decreasing in quantity.

In an effort to improve these issues from having degrading eelgrass beds, we want to plant more beds in specific areas that have limited eelgrass populations to help support their ecosystems and the bay area as a whole. We have proposed a protected habitat where the eelgrass can grow to maturity. By constructing flat, underwater structures out of concrete made from seashells and other San Francisco Bay sediment, we can grow eelgrass beds in captivity to maturity. The mature plants can be transported to areas like Richardson Bay near Sausalito where the eelgrass beds have been depleted.

Furthermore, because it is difficult to replant within areas where habitat has been destroyed by mooring, we also plan to build new habitats in safer and more manageable areas of the bay. For example, planting along seawalls, or creating floating platforms in deeper waters where eelgrass otherwise wouldn't have enough sunlight to grow.

SHOW:

1) **"CROP CIRCLE" photo** *(file:Mooring damage to eelgrass beds.docx)***.** Say: This is how the damage looks from the moorings.
2) **Timeline map of Richardson Bay** *(file:Eelgrass_timeline_Richardson_Bay.png)*. Say: For example, this is how much the eelgrass has reduced in one area of SF Bay known as Richardson Bay. It was this area in 2003 (*point*) and now it only covers this area in 2014 (*point*.)

Under the program, twenty acres per year will be planted over a 10-year period starting in 2020, so as to not overstress existing beds being used as donor material, for a total of an extra 200 acres by 2030. The extra carbon stored in plants and soil will represent the equivalent of 198 billion gallons of gasoline consumed. A team of 10 people each year will collect the shoots, rig up into transplant units, plant out, collect data on the new habitats, study whether the plants take to the seafloor and spread successfully, and make adjustments as needed for the next efforts. The Estuary Ocean Science Center run by San Francisco State University will be responsible for managing and conducting this project.

SHOW: *Say:* The beds would be planted in 3 areas *(point to each circled area on map):* Richardson Bay, Pt. Molate, and Coyote Point. *(file: InkedEelgrass_DistributionMarked_LI.jpg)*

Q3 INITIAL We are asking people about a ballot measure to fund this program. The ballot measure would be a one-time tax for all California individuals into a fund for the Estuary Ocean Science Center to be used solely for the purpose of planting, maintaining and monitoring 20 acres/year of eelgrass beds for ten years in the Bay to achieve 200 extra acres by 2030. If the measure is on the November 8 ballot, and the one-time tax would be an extra **$10** fee when you pay your taxes in 2020, would you vote for this program?

***Circle one:* YES (skip to Q4)** **NO (skip to Q5)**

Q4 FOLL-UP If the fee were **$15**, would you vote for the ballot measure?

***Circle one:* YES (skip to Q6)** **NO (skip to Q6)**

Q5 FOLL-DOWN If the fee were **$5**, would you vote for the ballot measure?

Circle one: **YES (skip to Q6)** **NO (skip to Q6)**

Q6 OPENWTP What would be the maximum willingness that you would pay to the Estuary Ocean Science Center for them to plant the eelgrass bedding habitats in the Bay area for a one-time cost fee through taxes?

$ ____________

Ask following question if interviewee put ANY money towards the program; otherwise go to Q9 PROTEST2.

Q7 REASON Why would you pay this amount? (***If person gives several reasons, ask for only the most important reason and check only one answer)***.

a. This program is worth this amount to me
b. The eel grass beds are worth this much to me to protect
c. To contribute towards a good cause
d. We have a responsibility to protect the ocean
e. Other reasons - *Specify:*____________

Also ask following question if interviewee put ANY money towards program; otherwise go to Q9 PROTEST2.

Q8 PROTEST1 What is the main reason for the maximum amount you would pay as opposed to any higher amount? ***(If a person gives several reasons, ask for only the most important reason and check only one answer).***

a. Eelgrass bed rehabilitation is not worth more to me
b. I can´t afford to pay more at this time
c. I feel like I have to contribute, but I don´t think protecting eelgrass beds is effectively going to help
d. I feel like I have to contribute, but I don´t think this program is going to effectively rehabilitate eelgrass
e. I am usually opposed to government programs
f. I don't believe in taxes so I don't want to pay a higher amount
g. Other Reasons- Specify:____________

Ask following question if interviewee said NO to all offered amounts and $0 in OPENWTP:

Q9 PROTEST2 What is the main reason you would pay zero? (***If person gives several reasons, ask for only the most important reason and check only one answer)***.

a. Eel grass bed rehabilitation is not worth anything to me
b. I can´t afford to pay at this time
c. I don´t think protecting eel grass beds is going to help
d. I don´t think this program is going to rehabilitate eel grass
e. I am opposed to government programs
f. It is unfair to ask me to pay for this program
g. I do not believe in more taxes so I do not want to pay them
h. Other Reasons- *Specify:*____________

DOI: 10.15351/2373-8456.1133

Q10: AGE: ______________

Q11 What is your Gender (code 1 for answer under matching column; otherwise code 0)

[FEMALE]	[MALE]	Prefer not to answer [PREFNO]	Other [GENOTR]
1	1	1	1

Q12 MARITAL Marital Status: *Circle one:* Single (code as 0) Married (code as 1)

Q13 What is your city and country of origin?

CITYO City of Origin: _________________________

COUNTRY Country of Origin: _________________________

Q14 CITYR What is the city you currently reside in? _________________________

Q15 EDUC What is the highest level of schooling you have completed?

- ☐ (1) High School Diploma
- ☐ (2) Some college experience
- ☐ (3) Bachelor's Degree
- ☐ (4) Master's Degree
- ☐ (5) PhD

Q16 INCOME What bracket best represents your individual yearly income?

- ☐ (1) less than or = $25,000
- ☐ (2) $25,000 - $50,000
- ☐ (3) $50,000-$100,000
- ☐ (4) $100,001 and above

Q17 VISIT Do you plan on visiting the San Francisco Bay within the next 5 years?: Yes, No

YES (1) NO (0)

Thank you for your time!

A.2 Images used during survey

Figure A.2.1. Mooring damage to eelgrass beds in Richardson Bay

Photo: Eric Heupel, in Audubon California (2018)

Figure A.2.2. Mooring damage to eelgrass beds in Richardson Bay

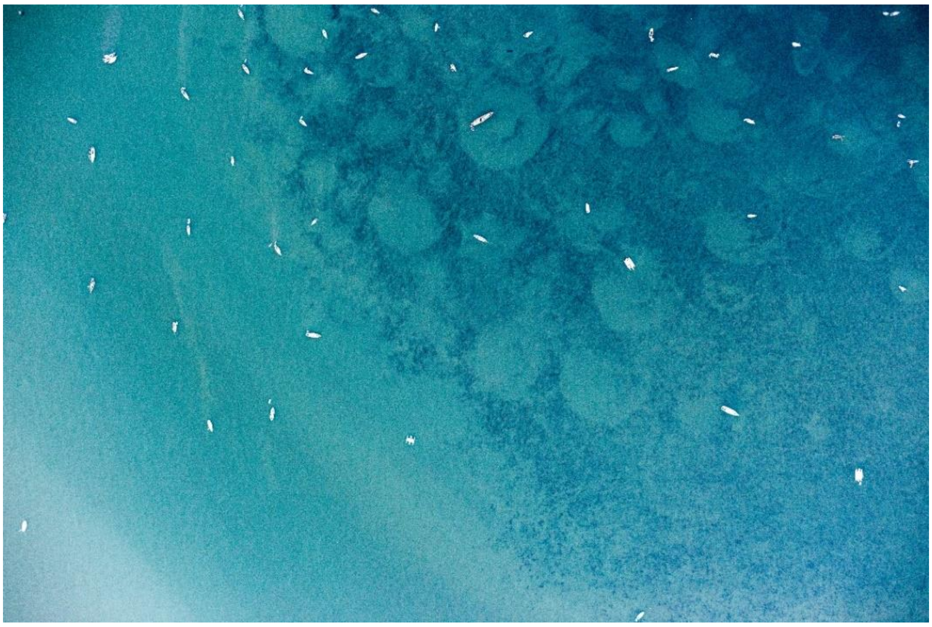
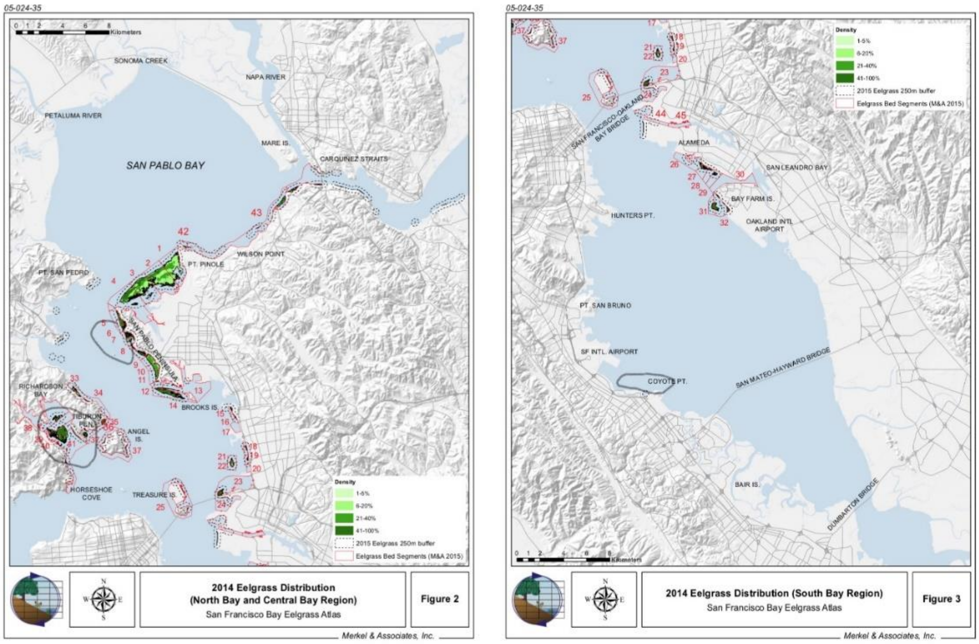


Photo: The 111th Group Photography

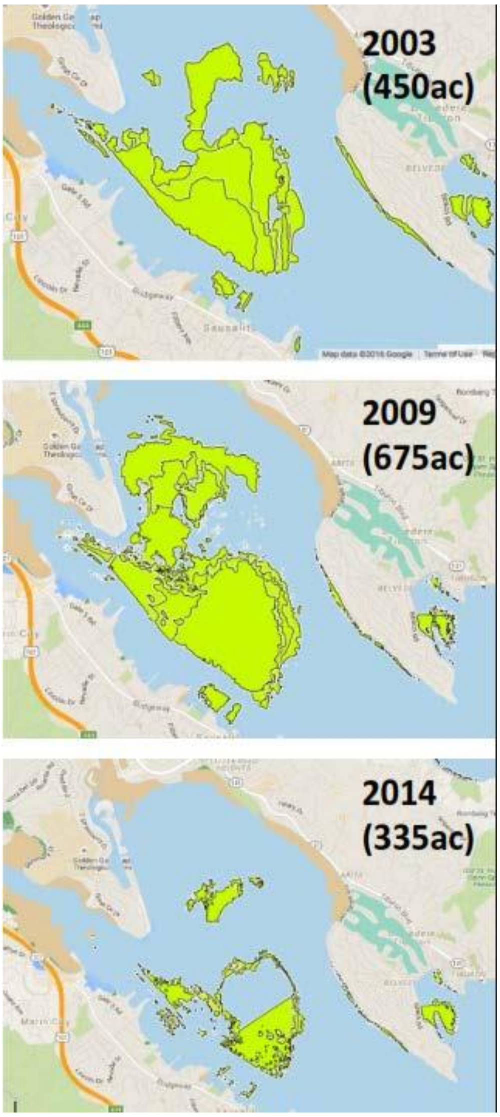
DOI: 10.15351/2373-8456.1133

Figure A.2.3. Hypothetical eelgrass restoration areas



Map: Merkel & Associates, Inc.; protection area indications: Aidan Cushing

Figure A.2.4: Eelgrass coverage in Richardson Bay, 2003, 2009, 2014



Map: Audubon California (2018)