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Combining Revealed and Stated Preference Models for Artificial Reef Siting: A Study in the Florida Keys

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Abstract

This paper investigates recreational divers' preferences for artificial reef diving and willingness to pay (WTP) for large ship, artificial reef site attributes in the Florida Keys. We investigate diver demand for existing decommissioned ships that have been sunk off the Florida Keys as well as demand for four new vessels that are available for disposal from the U.S. Department of Transportation Maritime Administration inventory. Using survey data from divers, we compare revealed preference (RP) site choices, stated preference (SP) choices from a discrete choice experiment, and joint RP/SP choices. Our analysis also incorporates stated attribute non-attendance (ANA) at the choice-task level. Our results indicate that the joint RP/SP models with stated ANA are preferred, leading to decreases in marginal WTP as well as decreases in the variability of marginal WTP estimates in the 95% confidence intervals. Results provide a framework for directing more efficient future decision making regarding sinkings at locations that will enhance welfare for divers.

Keywords: discrete choice experiment; artificial reefs; diving demand; willingness to pay

Introduction

Artificial reefs represent important assets for coastal communities. This includes the provision of private benefits through promoting recreational opportunities that attract divers and anglers – and the associated inflow of tourism-based expenditures from user-days generating local sales and income generation – to the area (Ditton and Baker 1999; Johns et al. 2001; Heitt and Milon 2002). For example, Johns et al. (2001) estimate that reef users spent approximately 10 million person-days using artificial reefs in southeastern Florida over a one-year period from 1997 to 1998, generating $2 billion in sales, $933 million in additional labor income, and 27,000 jobs to the region. More recently, Wallmo et al. (2021) combine survey data with national data from the Dive Equipment and Marketing Association (DEMA) to estimate diving and snorkeling participation over five counties in Southern Florida. They provide a DEMA-based estimate of 1,650,108 trips leading to a five-county increase of $902 million in sales, $340 million in additional labor income, and 8,668 jobs.

Artificial reefs also provide a suite of social benefits, including protection from shoreline erosion through wave attenuation and sand retention (Elliff and Silva 2017; Reguero et al. 2017); enhancing extremely valuable ecological systems that provide habitat to diverse aquatic species (Sánchez-Caballero et al. 2021); and mitigating the decline in ecosystem services associated with the global degradation in coral reefs (Higgins et al. 2022).

Artificial reef deployment can also provide welfare-enhancing diving opportunities for thousands of recreational divers. A relatively small number of studies - using revealed preference (RP) and stated preference (SP) methods – have examined and quantified the positive welfare effects attributed to reef diving. Some of these studies use contingent valuation methods to elicit divers' willingness to pay for recreational diving opportunities (Roberts et al., 1985; Ditton et al., 2001). Another subset focuses specifically on artificial reefs (Milon, 1989; Bell et al., 1998; Johns et al., 2001; Morgan et al., 2009).[1] For example, Morgan et al. (2009) design a travel cost model to value individual welfare associated with diving the World's largest artificial reef (the USS

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While artificial reefs can come in several forms (such as concrete and steel demolition debris, concrete reef balls, and dredge rock), reefing large, decommissioned vessels is becoming a popular way of increasing coastal communities' ecosystem assets. Over 700 ships have been deliberately sunk to serve as reefs off the U.S. coast, with approximately 400 ships reefed off the Florida coast (Pendleton 2004). Large, decommissioned ships are available for reefing under the U.S. Department of Transportation Maritime Administration (MARAD) vessel disposal program. The national defense reserve fleet was established after World War II to serve as an inventory of vessels available for use in national emergencies and for national defense. Vessels are periodically examined and reclassified. During that process some vessels are moved into a "non-retention" status and targeted for disposal. According to the MARAD vessel disposal program report, as of February 2022, there were approximately 88 vessels in the fleet with 12 vessels in non-retention status – MARAD vessels that no longer have a useful application and are pending disposition.

With the considerable costs associated with large-ship reefing, coastal communities often cost share in the process and could consider the implications of the types of ships available and the characteristics – or attributes – of the site location.[2] While research shows that considerable economic benefits are realized by divers of large-ship artificial reefs, the value associated with the different attributes of these reefs has not been investigated. The purpose of this research is to examine diver preferences for reefed ships and location attributes. Better understanding these preferences can lead to Pareto-enhancing decisions on the types of ships and locations for future sinkings, from a diver welfare perspective. Beyond the different dimensions of the vessels reefed and available for reefing under MARAD, other attributes of the reefing location may be important to divers.

[2] The costs of preparing a ship for reefing (including cleaning, preparing the vessel to meet environmental standards, towing, sinking) is estimated to be between $46,000 and $2million (Hess et al. 2001). However, reefing larger, decommissioned ships costs considerably more. For example, the costs to sink the former aircraft carrier (USS Oriskany) exceeded $10million.

This research conducts a discrete choice experiment (DCE) to examine recreational divers' preferences for reef diving and willingness to pay (WTP) for large ship artificial reef and site attributes. Using both existing decommissioned ships that have been sunk off the Florida Keys – namely the USS Vandenberg and Spiegel Grove – and four new vessels that are available for disposal from the MARAD inventory, respondents are asked to choose their next charter boat diving trip between a dive on an existing artificial reef, a new reef, or a no-trip option. The siting attributes of interest in the study are reef depth, boat time from shoreline to reef, and water column visibility at the reef site. This research adds to the existing body of knowledge regarding the welfare benefits of reefing large ships by estimating diver preferences for ship type and WTP for specific reef location attributes. Results will aid in directing more efficient future decision making regarding sinkings at locations that will enhance welfare for divers.

The analysis compares RP, SP, and RP/SP models. A number of discrete choice models have been utilized to combine discrete choice RP and SP data (Hensher and Bradley 1993; Green and Hensher 2007; Brownstone et al. 2000; Hensher et al. 2015; Whitehead and Lew 2020). RP and SP data cannot be simply stacked and jointly estimated because it is common for RP and SP error terms to have unequal variances (Swait and Louviere 1993). When combining RP and SP data, the model must account for these differences in scale parameters. We utilize the generalized mixed logit model (GMXL) to account for both scale and preference heterogeneity (Fiebig et al. 2010; Greene and Hensher 2010). The mixed logit model (MXL) and error components logit model (ECL) can be represented as special cases of the GMXL. Whitehead and Lew (2020) jointly estimate the demand for recreational fishing trips, constrain the RP travel cost and SP charter fee coefficients to be equal to zero and compare each of these models and find that willingness to pay estimates are similar. We estimate RP travel cost and SP dive fee coefficients separately. We then provide marginal WTP estimates based on contribution of these costs to total trip expenditures. Whitehead et al (2013) use a similar approach to welfare estimation with a joint RP/SP framework that combined single site recreation demand to NHL hockey games that separately modeled NHL ticket price and travel costs.

Our analysis also incorporates stated attribute non-attendance (ANA) at the choice-task level (Lew and Whitehead 2020). Hindsley et al. (2022) use the inferred ANA approach and find that

ANA reduces the differences between RP and SP willingness to pay estimates. In this paper the stated ANA validation approach is utilized by estimating two parameters for attributes. One is for attributes respondents identify as attended and the other for those that are non-attended. In previous work, Hindsley et al. (2020) use the validation approach with serial stated ANA – where respondents are asked follow-up ANA after all choice sets have been presented – in order to address hypothetical bias. This effort extends their approach by using choice task ANA where respondents face ANA follow-up questions after each of four choice sets faced by the respondent.

From a modeling perspective, results show that the joint RP/SP models are preferred – compared to separate RP and SP models – with the inclusion of RP data decreasing marginal WTP in absolute terms as well as in the variability of WTP estimates in the 95% confidence intervals. We also calculate marginal WTP from the joint RP/SP models based on an expenditure share approach (Whitehead et al. 2013) that incorporates both trip fee and travel cost into the marginal WTP estimate based on their share of the contribution to total trip expenditures. Results from this approach indicate lower estimates of marginal WTP and lower variability in 95% confidence intervals. Further, including stated ANA decreases marginal WTP measures, indicating a reduction in hypothetical bias. In terms of diver preferences, model results from the joint RP/SP models indicate that both depth and boat time are regarded as disamenites to divers, with deeper reefs and longer boat times reducing the likelihood of a dive trip. However, visibility is seen as a positive attribute to the reefing location with diver WTP increasing with improvements in water column visibility.

The next section of the paper overviews the survey design and describes the data. Then, the DCE design is outlined, followed by a description of the models. Finally, model results and willingness to pay measures are presented, together with concluding remarks.

Survey Design and Data Description

Without any reef-specific primary diving data being available, a survey of reef divers is developed to examine diver preferences for new large-ship artificial reefs. Florida has the most active and diverse reefing system in the United States. Within this system, the Florida Keys is the most popular diving destination with a Year 2000-2001 estimate of 7.55 million person-day dives on both natural and artificial reefs in the area (Johns et al. 2001). With the Florida Keys as the diving region of interest, the sample population is drawn from Florida fishing license holders' email addresses gathered from the Florida saltwater fishing license database (provided by the Florida Fish and Wildlife Conservation Commission). Recreational divers are self-identified in the database. The survey design is developed in the Qualtrics, Inc. software and administered via email. A pilot test was sent to 500 respondents. Feedback from 94 completed responses to the pilot survey aided survey design and refinement of proposed fee structures. The survey was sent to 1,437 respondents. Follow-up survey reminders, as suggested by Dillman (2011) were also sent to respondents. After deleting any incomplete responses, the full sample was 215 divers (providing an overall response rate of 15 percent).

The combined RP/SP survey design has four sections. Section 1 elicits respondents' reef diving behavior and attitudes and preferences toward artificial reef type and site attributes. Section 2 collects data on divers' revealed preferences related to their current and past diving behavior. Section 3 collects SP data concerning respondents' stated choices for their next charter boat diving trip using a DCE. Finally, the fourth section collects information regarding the socio-economic characteristics of the respondents.

The survey begins by asking respondents questions regarding diver behavior and reef preferences. Table 1 shows that a large majority of divers are recreational divers (as defined by diving to no deeper than 130 feet of the surface with no decompression limits). Within the Keys' reef system, two large ship reefs are currently available to dive. These are the USS Vandenberg and the Spiegel Grove. Details of both vessels are provided in the Appendix, however, the USS Vandenberg served as a missile tracking ship until she was retired in 1983. She was sunk in 2009 off the coast from Key West and is the second-largest artificial reef in the world. The Spiegel Grove's main function was to carry a large contingent of US Marines and beach assault vehicles. She was reefed in 2002 in the northern part of the Keys, off the coast from Key Largo. Table 1 shows the percentage of respondents that have taken a dive trip to these reefs and the Keys region in general. Half of the sample have dived the Speigel Grove reef with fewer respondents having dove the Vandenberg reef.

Preferences for reef and site attributes are also elicited. Respondents are asked on a five-point Likert scale (ranging from 1 = “Not Very Important at all” to 5 = “Very Important”) to state the importance of different reef and site attributes in their diving trips. Table 2 shows the mean response per attribute and the distribution across the Likert scale. Water visibility appears to be the most important attribute for divers with approximately 70% of respondents indicating that visibility is either “important” or “very important”. Depth also rates, on average, as “moderately important” with 38% of respondents stating that the attribute is either “important” or “very important”. Boat time to the reef from the shoreline is rated as the least important attribute.

The second component of the survey elicits respondents’ revealed preferences for trips over the past five years (see Table 3). The average number of trips to the Keys, per respondent, over this time period was 9 with a maximum number of 400. On average, 0.7 charter boat dive trips were made to the USS Vandenberg (ranging from 0 to 50), with 2 trips to the Spiegel Grove (ranging from 0 to 200), over the same time period.

A sociodemographic breakdown of respondents is provided in Table 4. The average respondent in the sample is male, 58 years of age, earning over $100,000. Approximately 75% of respondents have a graduate degree or higher. The sociodemographic breakdown suggests that the sample is representative of the diving population as it mirrors other studies that have sampled the recreational diver population (see Ditton and Baker 1999; Morgan, Huth, and Massey 2009; Huth et al. 2015). Essentially, due to the high cost and travel-intensive nature associated with recreational diving, the diver population tends to be a well-educated and higher income-earning cohort.

Discrete Choice Experiment

The DCE explored the trade-offs that divers make between artificial reef characteristics. Before the DCE section, the MARAD inventory and potential for new decommissioned vessels to be deployed as new reefs is described to the respondent. A brief history of the two existing reefs –

USS Vandenberg and Spiegel Grove – is provided (together with a map showing the location of both in the Keys area). In designing the DCE, to provide realistic future reef opportunities, four existing and potential ships available for reefing under MARAD's vessel disposal program inventory are used. The four ships were chosen as potential reefing alternatives that provided a variation in type and size. They are 1) Golden Bear Training Ship; 2) Fast Sealift Ship; 3) SS Wright; and 4) Freedom Star (see the Appendix for more details on each vessel). Before the DCE choice tasks, a photograph of each vessel, a description, and their dimensions are shown and described to the respondent. The reef attributes that are pertinent to the study were then defined (see Table 5). There are five attributes included in the DCE design: 1) vessel size; 2) depth to reef; 3) boat time to reef; 4) water column visibility at the reef site; and 5) charter boat trip fee The list of attributes and levels are selected based on initial interviews with divers. Each attribute is defined and described to the respondent before the choice tasks. Our goal is to choose attributes relevant to the placement of new artificial reefs, but potentially generalizable to locations outside the Florida Keys.

In the DCE, respondents make four consecutive choices related to diving options in the Florida Keys. Each individual choice consists of three alternatives: 1) a status quo option consisting of one of two existing artificial reefs in the Florida Keys (Vandenberg or Spiegel Grove); 2) a new option consisting of one of the four proposed artificial reefs from the MARAD program (Golden Bear, SS Wright, Fast Sealift Ship, and Freedom Star); and 3) a no-trip option (opt out).
The levels of these attributes are fixed for the existing artificial reefs in the status quo option (Vandenberg, Spiegel Grove), but vary across choice sets for the proposed artificial reefs from the MARAD program (see Table 5). Figure 1 provides an example choice set.

We used the Ngene software for the DCE design process (Choice Metrics 2017). Our design had 20 unique choice scenarios that were divided between 5 blocks. The initial step employed an optimal D-efficient design consisting of the status quo artificial reef option, the proposed artificial reef option, and the opt out. The fractional factorial design focuses on the balance of attributes within the DCE. Across all choice scenarios, each attribute level receives equal representation within our proposed artificial reef alternative. Each status quo reef type (Vandenberg, Speigel Grove) and proposed reef type (Golden Bear, SS Wright, Fast Sealift Ship, and Freedom Star) receive equal representation within each block. We randomly assign each respondent to 1 of the 5 blocks. The respondent then faces four randomly ordered choices between the status quo diving option, the hypothetical new reef option, and a no-trip option (opt out). Respondents are shown a sample choice question and description of the 3 choice options before beginning the DCE.

Following each choice set, respondents are asked several follow-up questions regarding their choice. First, they are asked to state how certain they are, on a Likert scale ranging from 1 to 10, their level of certainty regarding their choice. Then, on a five-point Likert scale – ranging from "1 = Not Very Important" to "5 = "Very Important" – respondents were asked to rate how important each attribute was in their trip choice. Finally, respondents were also given a list of all attributes in the choice set and asked to identify any that were not important in their trip choice response.

Models

We analyze both RP and SP data representing discrete choices made by individuals between multiple diving (and non-diving) alternatives. We utilize RP diving trips and SP diving trips, via a DCE, to analyze individuals' preferences for diving attributes with a random utility model (RUM) (McFadden 1974). The RUM decomposes the utility associated with a given choice between the observed and unobserved components of those choices. Let U_{njt} denote the utility individual *n* has for alternative *j* in choice situation *t*. In RUMs, we can decompose U_{njt} into an observable component of utility, V_{njt}, and an unobserved component of utility, ε_{njt}, with a standard deviation (or scale parameter), σ, such that

$$U_{njt} = V_{njt} + \varepsilon_{njt}/\sigma \quad (1)$$

After multiplying all components of utility by the scale parameter, we represent utility to be linear in observed attributes for each alternative *j* and the corresponding parameters, β, such that

$$U_{njt} = \sigma_n \sum_{k=1}^{K} \beta_{nk} x_{njtk} + \varepsilon_{njt}, \quad (2)$$

where β_{nk} captures the marginal utility of attribute k. In the utility function, U_{njt}, the unobserved component of utility, ε_{njt}, is assumed to be independently and identically (IID) extreme value. When a single data set is used, the scale parameter is normalized to one in order to identify coefficients. Given the unobserved elements of utility, we consider an individual n choosing alternative j is

$$P_{njt} = P\left(\sigma_n \sum_{k=1}^{K} \beta_{nk} x_{njtk} + \varepsilon_{njt} > \sigma_n \sum_{k=1}^{K} \beta_{nk} x_{nitk} + \varepsilon_{nit};\ \forall i \in J\right). \qquad (3)$$

Under the generalized mixed logit model (GMXL), the marginal utility for attribute k is

$$\beta_{nk} = \sigma_n \bar{\beta}_k + [\gamma + \sigma_n(1-\gamma)]\nu_k z_n \qquad (4)$$

where the scale parameter takes the form

$$\sigma_n = \exp\left(-\tau^2/2 + \theta SP + \tau w_n\right). \qquad (5)$$

In (4), $\sigma_n$represents the scale parameter for individual *n*, $\bar{\beta}_k$ represents the mean for the distribution of parameters, γ is the weighting variable that allows scaling of the unobserved heterogeneity in parameters, ν_k represents the spread of preferences around the mean, and z_n represents random draws from a specified distribution for each individual *n*. In (5), τ is the coefficient on the unobserved scale heterogeneity, SP is equal to one for the stated preference data source and zero otherwise, w_n is a weight assumed to follow a standard normal distribution. This model captures different uncertainty levels with respect to the choices made through the estimation of this scale parameter. There are several special cases of GMXL models. In our application, we estimate a ECL($\tau = 0$), a MXL ($\tau = 0$), and a scaled MXL ($\gamma = 0$).

Our analysis also accounts for stated attribute non-attendance at the choice-task level for the boat trip fee variable in SP data. Attribute non-attendance (ANA) refers to a choice processing strategy in which respondents ignore attributes in a choice set (Hensher et al. 2005, Campbell et al. 2008, Hensher 2008, Scarpa et al 2009, Hess and Hensher 2010, Scarpa et al 2012). ANA can can be seen as a rational response by survey respondents to complex choices, rooted in the concept of bounded rationality (Hensher 2014), and can be applied to capture more realistic information processing strategies and to help mitigate hypothetical bias (Koetse 2017; Lew and Whitehead 2020). ANA can be inferred using latent class models or stated using follow-up questions within the survey instrument. For stated ANA, follow up questions can be placed after each individual choice set (choice task ANA) or once following all choice sets (serial ANA). We utilize the validation approach to stated ANA, which estimates two parameters for attributes. One is for attributes respondents identify as attended and the other is for those that are non-attended (Scarpa et al., 2012; Caputo et al. 2018). The validation approach assumes respondents may have utility or disutility for attributes even though they reported to ignore it. Accounting for both attended and non-attended attributes separately addresses potential model misspecification (Caputo et al. 2018). Hindsley et al. (2020) use the validation approach with serial stated ANA to address hypothetical bias. We extend their approach to using choice task ANA for all DCE attributes.

The probability that respondent *n* in choice task t is observed to choose alternative j is

$$P_{njt} = \int_{\beta} P_{njt}(\beta) f(\beta|\theta) d\beta \quad (6)$$

where $f(\beta|\theta)$ is the probability density function of β, given the distributional parameters θ.

Since the integral in (6) does not have a closed form solution, we approximate the model using simulation. We compute the simulated log-likelihood function using the expected probability computed from (6) using 800 halton draws. The simulated maximum likelihood model is

$$SLL = \sum_{n=1}^{N} \log E\left(\prod_{t \in T} \prod_{j \in J} \left(P_{njt}\right)^{y_{njt}}\right). \quad (7)$$

We use the independently estimated RP and SP models and the jointly estimated RP-SP model to estimate willingness to pay values for characteristics of diving trips. We estimate the willingness-to-pay for attribute *k* as

$$WTP_k = \frac{\beta_k}{\beta_c} \quad (8)$$

such that, β_k represents the coefficient for attribute *k* and β_c represents the diving fee cost coefficient. We use various cost coefficients in the WTP calculations. We use the dive fee coefficient in the base RP/SP model and separate dive fee coefficients for those who attend to the fee and those who say they don't in the ANA RP/SP model. Finally, we incorporate the RP travel cost coefficient by weighting the travel cost and dive fee coefficients by their expenditure shares.

We take an approach used by Whitehead et al. (2013) and adapt it to a RUM framework. Our application estimates the willingness-to-pay for attribute k as

$$WTP_k = \frac{\beta_k}{(S_c * \beta_c) + (S_{tc} * \beta_{tc})} \quad (9)$$

such that, S_c represents the expenditure share associated with the diving fee cost, S_{tc} represents the expenditure share associated with the travel cost, β_c represents the diving fee cost coefficient, and β_{tc} represents the travel cost coefficient.

Results

The RP data were constructed from diver trips to the Vandenberg and/or Spiegel Grove over the previous five years (see Table 6). Trip counts to these sites were not available for the previous year alone. As such, the RP choices account for a 5-year span of time and it was assumed that each individual had a minimum of five choices (Visit/Opt Out) to each site over that period for a minimum total of 10 total choices. Roughly 96% of sampled divers make 10 RP choices in our dataset (see Table 7). For divers who visit one of the sites more than five times in a year, the total number of choices made increases according to the additional number of visits to that site. For example, if an individual makes two visits to the Vandenberg and 11 visits to Spiegel Grove, they will have a total of 16 choices. This means five choices associated with the Vandenberg – two choices to visit and three choices to opt out – and 11 choices with the Spiegel Grove (11 choices to visit). While the minimum number of RP choices made was 10 the maximum number of choices was 80.

The RP travel cost variable is constructed to account for both the round trip operating and ownership costs for vehicles and the opportunity cost of time for traveling either to the Vandenberg or the Spiegel Grove. The explicit travel costs are the product of the composite national average operating, ownership cost per mile – \$0.6188 rounded to \$0.62 (AAA 2019) – and round-trip travel distance. We calculate the opportunity cost of time at 1/3 of the hourly wage with travel time determined using an average speed of 45 miles per hour (Lupi et al. 2020). On average, respondents have a round trip travel distance of 925 miles to dive on the Vandenberg (Key West) and 740 miles to dive on the Spiegel Grove (Key Largo). The average explicit RP travel cost to the Vandenberg is \$574 with a range of \$4 to \$3,644. Accounting for the opportunity cost of time, the average RP travel cost to the Vandenberg is $936 with a range of $7 to $7,997. The average explicit RP travel cost to the Spiegel Grove is $459 with a range of $11 to $3,524. With the opportunity cost of time, the average RP explicit travel cost to the Spiegel Grove is $751 with a range of $17 to $7,733.

In total, we estimate five models (see Tables 8 and 9). We first estimate separate RP and SP models. We utilize an error component logit model for the RP data and a mixed logit model for the SP data. We then stack the RP and SP data and estimate a generalized mixed logit model. With the RP data, a lack of variability in site attributes limits our ability to include diving characteristics in the model. The RP specification includes the charter trip fee, the travel cost to the site, and a no-trip error component that is normally distributed with a mean of zero. We estimate two SP models, a base model and a model accounting for both stated attribute attendance and non-attendance in the SP variables. Both SP specifications utilize fixed coefficients for the proposed reef (Golden Bear, SS Wright, Freedom Star, and Fast Sealift) and the charter boat fee. These models also incorporate normally distributed random coefficients for a no-trip alternative specific constant (opt out), diving depth (in feet), diving visibility (in feet), and charter boat travel time (in minutes). Finally, we estimate two generalized mixed logit models, which utilize stacked RP and SP data. Here, we estimate a base model and a model accounting for stated attribute and non-attribute attendance (SP data only). We utilize fixed coefficients for the proposed reef (Golden Bear, SS Wright, Freedom Star, and Fast Sealift) and the charter boat fee. These models also incorporate normally distributed random coefficients for a no-trip alternative specific constant (opt out), diving depth (in feet), diving visibility (in feet), the charter boat travel time (in minutes), and the round-trip travel cost with opportunity cost of time set at 1/3 of hourly wage.

The separate RP charter boat selection and the SP choice experiment models are presented in Table 8. In the RP model, both the travel cost coefficient and the charter boat trip fee are negative and statistically significant at the .001 level. The no-trip error component has a zero mean with a large standard deviation that is highly statistically significant. In the base SP model, we include a no-trip, alternative specific constant (opt out) with a normally distributed, random coefficient. We find a negative sign for the mean opt out coefficient with statistically significant results at the .01 level. We do not find a statistically significant result for the standard deviation of the random coefficient. Rather than an alternative specific constant representing all MARAD boats, we include boat-specific constants for each individual MARAD boat. We only find statistically significant results for two boats, with the coefficient on Golden Bear, negative and significant at the .1 level and the coefficient on Freedom Star, negative and significant at the .01 level. The coefficient on the Freedom Star is almost four times larger (in absolute terms) than the Golden Bear. These results indicate that divers have similar preferences for diving on two of the proposed MARAD reefs, the SS Wright and the Fast Sealift Ship, when compared to the existing reefs (the Vandenberg and USS Spiegel Grove). On the other hand, divers prefer the existing reefs to the Golden Bear and the Freedom Star, with divers preferring the Freedom Star reef the least. We also utilize three reef characteristics in our design: 1) the depth to the reef deck (in feet); 2) the boat time to the reef (in minutes); and 3) the average visibility at the reef (in feet). For the depth to the reef deck, we find statistically significant results for the mean and standard deviation of the random coefficient. The point estimates indicate that roughly 87% of divers view increased reef depth as a disamenity within our proposed data range. Our estimates for boat time to reef do not lead to a statistically significant sign on the mean but we do find a statistically significant sign on the standard deviation for the random coefficient. As such, boat time to the reef can be considered both an amenity and a disamenity based on the individual preferences of the diver. Last, divers perceive the average visibility at the reef as an amenity, with a statistically significant mean at the .01 level but no statistical significance for the standard deviation of the random coefficient.

When we account for stated attribute and non-attribute attendance for the model variables, we find modest changes in results when compared to those in the basic SP model. The SP attribute non-attendance model only represents a small improvement in model fit. We do find evidence that respondents exhibit preferences for some variables identified as non-attended. For depth to reef, there is a small decrease in preference heterogeneity for those who identify the variable attended versus those who say it is non-attended in the model. We do find the standard deviation for the random coefficient of boat time to reef now to be statistically significant at the .1 level when identified as attended and at the .05 level when identified as non-attended. When attended, visibility has a positive effect on choice – a result which is significant at the .01 level. This model includes two representations of the fee variable: 1) the attended boat fee; and 2) the non-attended boat fee. We find the attended boat fee to be negative and statistically significant at the .01 level. The non-attended boat fee is not statistically significant. The coefficient for the attended boat fee is larger in magnitude than the coefficient of the boat fee in the base SP model, indicating some mitigation of hypothetical bias (Koetse 2017; Hindsley et al 2022).

Next, we estimate two RP/SP models using the Generalized Mixed Logit Model, a base model and an attribute non-attendance model. These models have the same general specifications as the SP models with a few alterations. In both models, we include the round-trip travel cost for RP choices and estimate the SP contribution to the τ scale, θ. We also restrict the γ weighting parameter to 0, making our procedure a scaled mixed logit model

For our base GMXL model, we find a negative, statistically significant value for the mean coefficient for the no-trip ASC, but do not find a statistically significant result for the standard deviation of this random coefficient. We do find an increase in the magnitude of the influence of the no-trip estimate in the RP/SP data when compared to the SP data. Among the MARAD boat-specific constants, the Golden Bear estimate has a negative sign and is significant at the .05 level. The influence of this boat on diver preferences is similar to the SP data. The negative coefficient for the Freedom Star has less influence in the base GMXL model when compared to the SP model and is significant at the .05 level. In terms of reef attributes, for depth to the reef deck, we find statistically significant results for the mean and standard deviation of the random coefficient. The point estimates indicate that roughly 91% of divers view increased reef depth as a disamenity. Using the RP/SP data, our estimates of the mean for boat time is negative and has a statistically significant sign at the .01 level. The divers perceive the average visibility at the reef as an amenity, with a statistically significant mean and standard deviation at the .01 level. Just under 82% of respondents would gain utility from an increase in visibility. The coefficient for the charter boat fee, a fixed coefficient, is negative and statistically significant at the .01 level. The mean travel cost coefficient is negative. The mean and standard deviation for the travel cost coefficient are both statistically significant at the .01 level. Finally, the coefficient on the SP contribution to scale is negative and statistically significant at the .01 level. This shows a smaller variance in the SP data as compared to the RP data.

The GMXL model with attribute non-attendance only has small differences as compared to the base GMXL model and exhibits a slightly worse model fit. We find the opt out alternative specific constant significant at the .01 level with a magnitude similar to the SP model. In this model, the Golden no longer has a statistically significant influence on diver preferences. The coefficient for the SS Freedom is significant at the .01 level. We find the increased reef depth to have similar influence for those who both state it as attended and non-attended. The mean and standard deviations of these coefficients are significant at the .01 level. The mean coefficient for boat travel time to reef is negative and significant at the .05 level for those who state it as attended, but not significantly different than zero for those who state it non-attended. Conversely, the standard deviation for the estimated parameter is not significant for those who state it attended but is significant at the .01 level for those who state it non-attended. Among those who state it attended, the average visibility at the reef has a positive, statistically significant mean coefficient, but now it also has a statistically significant standard deviation for the random coefficient. Roughly 84% of divers view average visibility as a positive amenity. In this model, we find a negative, statistically significant result for the attended and non-attended charter boat fee variables. In absolute terms, the attended fee coefficient is almost double that of the non-attended fee coefficient. As a whole, this model only represents a small statistical improvement over the base GMXL model.

Willingness to Pay

We are unable to estimate WTP measures using the RP model due to a lack of variability in our characteristics of interest. We are able to estimate WTP for the SP models and the jointly estimated RP/SP models. The coefficient on the dive fee plays a large role the determination of value, so we are interested in mitigating potential hypothetical bias in the SP cost coefficient. We utilize the delta method to calculate 95% confidence intervals for the depth to reef, the boat time to reef, and the average visibility at the reef. All estimates can be found in Table 10. All comparisons are made in absolute terms.

Estimates from all models indicate that divers are willing to pay more for reefs in shallower water. This is not surprising given that the majority of divers are recreational divers that stay closer to the surface. In our base model, the marginal WTP for an additional foot in depth to the reef deck is -$4.10 (95% CI: -$6.92, -$1.29). When we account for stated attribute non-attendance, the point estimate changes by 18% to -$3.36 (95% CI: -$5.20, -$1.52). While we do have considerable overlap in confidence intervals, we observe a narrowing of the interval in addition to the decrease in value. In our base GMXL model, the marginal WTP estimate is-$2.53 (95% CI: -$3.15, -$1.91) – a change of 38%. The spread of the base SP MWTP confidence interval for this measure is roughly 4.5 times larger than the RP/SP base confidence interval. When we account for attribute non-attendance in the GMXL model, our marginal WTP estimate changes by 50% compared to the base SP estimate with a value of -$2.04 (95% CI: -$2.49, -$1.58). The range of the base SP 95% confidence interval ends up being more than 6 times wider than the RP/SP GMXL model after accounting for attribute non-attendance. Last, we also provide additional estimates for MWTP where we incorporate the RP travel cost coefficient by weighting the travel cost and dive fee coefficients by their expenditure shares (78% travel cost/22% dive fee). For clarity, we will refer to these joint RP/SP estimates as expenditure share models. Under the RP/SP base - expenditure share model, the marginal WTP for an additional foot in depth to the reef deck is -$1.06 (95% CI: -$1.31, -$0.81). This represents a 74% change from the base SP model and the SP model's 95% confidence intervals are over 11 times wider. Under the RP/SP ANA – expenditure share model, the marginal WTP for an additional foot in depth to the reef deck is -$0.93 (95% CI: -$1.16, -$0.70). This represents a 77% change from the base SP model. When compared to the RP/SP ANA model estimates, the SP model's 95% confidence intervals are over 12 times wider. Overall, results suggest that there is much less variability in marginal WTP estimates when incorporating RP data into our models.

In terms of boat time to a reef, marginal WTP estimates are not statistically different than $0 for the two SP models. For the RP/SP base and RP/SP ANA models, marginal WTP estimates of boat time to reef are -$2.83 (95% CI: -$4.27, -$1.38) and -$2.37 (95% CI: -$3.95, -$0.76), respectively. Confidence intervals suggest no statistical differences in marginal WTP between these two RP/SP models. Under the RP/SP base – expenditure share model, the marginal WTP for an additional boat time to reef is -$1.19 (95% CI: -$1.99, -$0.38). Under the RP/SP ANA – expenditure share model, the marginal WTP for additional boat time to reef is -$1.08 (95% CI: -$1.91, -$0.24). In both expenditure share models, the confidence intervals are between 1.7 and 1.8 times narrower than using the coefficient for the charter boat fee alone.

With respect to average water column visibility around the reef, marginal WTP for an additional foot in average visibility – in the base model – is not statistically significant. In our SP attribute non-attendance model, the marginal WTP estimate is $3.00 (95% CI: $0.08, $5.91). In our base RP/SP model, the marginal WTP estimate is $1.19 (95% CI: $0.25, $2.14) – a decrease from the ANA SP result of 60%. When we account for attribute non-attendance in the RP/SP model, our marginal WTP estimate is $1.44 (95% CI: $0.53, $2.35), representing an 83% decrease from the SP ANA result. Again, we find significantly less variability in marginal WTP estimates when incorporating RP data into our estimates.

When we estimate the expenditure share models, willingness to pay estimates are less than 50% of the corresponding WTP estimate using only the SP dive fee coefficient and we again see a dramatic reduction in the uncertainty of these estimates, as represented in the 95% confidence intervals.

Conclusions

Artificial reefs represent important assets to coastal communities. Not only do they attract external dollars into these areas from diving and fishing tourism but they also provide a suite of social benefits through ecosystem services, storm protection, and mitigation of services provided by a declining natural reef system. While there are several different artificial reef structures – bridge rubble, submerged subway cars, oyster shells, concrete balls, etc. – reefing decommissioned large ships is seen as a popular and cost-effective method of disposing of these vessels. They also provide a welfare-enhancing diving opportunity for thousands of recreational divers.

A discrete choice experiment survey was constructed and emailed to recreational divers with a Florida Fish and Wildlife license (required to dive in Florida coastal waters). Within the DCE, respondents were presented with four choice sets with three options for their next dive trip in each – dive an existing reef (either the USS Vandenberg or Spiegel Grove), dive a new reef, or opt out of a dive trip. Four new potential ships for reefing (currently in the MARAD inventory) were randomly assigned in the new reef dive option. Four reef diving attributes were also provided in each option (depth, time to reef, visibility, and charter boat fee). Results show that the joint RP/SP models are preferred over separately estimated RP and SP models. The inclusion of RP data led to decrease in marginal WTP in absolute terms and the variability in the mean marginal WTP estimates decreased with a narrowing of the 95% confidence intervals.

To account for stated attribute non-attendance, follow up questions were placed after each individual choice set. The validation approach to stated ANA at the choice-task level was utilized by estimating two parameters for attributes – one for attributes that respondents identify as attended and one for those that are non-attended. Use of stated ANA appears to decrease marginal WTP, indicating a reduction in hypothetical bias.

Incorporating the RP travel cost coefficient into WTP measurement further reduces welfare estimates. This suggests that either the SP data may suffer from hypothetical bias or divers treat travel costs and dive charter fees differently when making trip decisions. In addition to the decrease in welfare estimates, this approach also leads to a significant decrease in variability in the 95% confidence intervals of these estimates. Past research has assumed that different RP and SP coefficients reflect hypothetical bias and have used the calibration approach to WTP estimation, constraining RP and SP cost coefficients to be equal, or estimated separate WTP estimates implied by the RP and SP data. We have introduced a weighting approach assuming that divers treat the two costs differently based on their proportional contribution to total expenditures, which we call the expenditure shares models. More research is warranted in this area.

Coastal communities often cost share in the process of obtaining a ship for reefing. However, the decision-making process that underlies the obtained vessel and its reefing location is not necessarily efficient. The purpose of this research is to examine diver preferences for reefed ships and location attributes. Better understanding these preferences can lead to Pareto enhancing decisions on the types of ships and locations for future sinkings, from a diver welfare perspective. Our approach focuses specifically on divers and only targets large artificial reefs. Future research should consider incorporating both natural and artificial reefs and should expand on the type of user that benefit from these reefs (such as anglers). Our study also relies on a longer time frame (5 years) to model revealed preferences. Future approaches would benefit from a shorter time frame, especially if dealing with activities associated with higher frequency of use.

Results indicated that an increase in depth from the surface to the vessel was generally seen as a disamenity, with deeper reefs reducing the likelihood of a dive trip. There were mixed results for boat time to reef with joint RP/SP models indicating that shorter boat times are preferred. In the RP/SP model, almost 90% of divers view this as a disamenity. Finally, visibility is seen as a positive attribute to the reefing location with respondents willing to pay between $1.09 and $2.86. A one-foot increase in depth reduced diver willingness to pay for a dive trip by between $2.18 and $3.29.

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Figure 1. An Example Choice Set

Please choose a trip type to indicate your preferred trip.

Features	Trip A	Trip B	No Trip
Vessel Type/Size:	**A charter boat trip to the USS Vandenberg**  Length: 523 Feet Beam: 72 Feet	**A charter boat trip to the Freedom Star**  Length: 175 Feet Beam: 37 Feet	Do something else, but do not take a diving trip to the Keys.
Sinking Depth to the Vessel's Deck:	110 feet.	40 feet.	
Boat Time to Reef (in minutes):	40 minutes.	40 minutes.	
Average Visibility:	25 feet.	75 feet.	
Charter Boat Trip Cost (With No Gear):	$50	$100	

Which trip would you take?

- Trip A
- Trip B
- No Trip

Table 1. Diver behavior and Reef Preferences

Variable	Definition	Mean	Min	Max
Rec_Diver	= 1 if primarily a recreational diver	0.94	0.00	1.00
Keys	= 1 if taken a diving trip to the Keys	0.93	0.00	1.00
Vandenberg	= 1 if taken a trip to dive the Vandenberg	0.17	0.00	1.00
Spiegel Grove	= 1 if taken trip to dive the Spiegel Grove	0.50	0.00	1.00

Table 2. Importance of Reef and Site Attributes

Variable	Definition	Mean (Std. Dev.)	1 = "Not Very Important at all"	2	3	4	5 = "Very Important"
Size	Importance of Vessel Size	2.86 (0.89)	9.30	16.28	57.21	13.49	3.72
Time	Importance of boat time to the reef	2.63 (0.94)	12.56	29.77	41.86	13.95	1.86
Depth	Importance of Depth	3.18 (1.05)	6.98	16.28	39.07	27.44	10.23
Visability	Importance of Water Visability	3.84 (0.82)	1.86	2.33	24.65	52.56	18.60
Fee	Importance of Charter Boat Fee	2.94 (1.12)	13.49	18.60	34.88	26.05	6.98

Table 3. Dive Trips to the Keys Over the Past Five Years (Obs = 214)

Question	Mean	Standard Dev.	Min	Max
Trips to Keys over last 5 years	9.02	36.07	0.00	400.00
Trips to the Vandenberg	0.65	3.78	0.00	50.00
Trips to the Spiegel Grove	2.09	15.24	0.00	200.00
Travel Cost to Vandenberg	$573.81	$465.85	$3.85	$3,643.70
Travel Cost to Spiegel Grove	$458.96	$463.02	$11.33	$3,523.50

Table 4. Sociodemographic Breakdown (Obs = 214)

Variable	Mean	Standard Dev.	Min	Max
Gender (1=male)	0.89	0.30	0.00	1.00
Age (in years)	58.41	10.30	28.00	81.00
High School	0.07	0.25	0.00	1.00
Technical Degree	0.08	0.28	0.00	1.00
Some College	0.12	0.32	0.00	1.00
College	0.45	0.50	0.00	1.00
Grad School	0.29	0.45	0.00	1.00
Income	101.93	62.90	10.00	200.00

Table 5. Vessel and Reef Attributes

Attribute	Definition	Levels
Vessel Size	Length and beam (width at its widest point) of vessel, in feet	Vandenberg: Length=523ft; Beam=72ft. Spiegel Grove: Length=510ft; Beam=84ft. Golden Bear: Length=500ft; Beam=72ft. Fast Sealift Ship: Length=946ft; Beam=106ft. SS Wright: Length=602ft; Beam=90ft. Freedom Star: Length=175ft; Beam=37ft.
Depth	Distance, in feet, measured from the water's surface to the reef's deck area	40, 75, 110, 145
Time	Measured, in minutes, from the shoreline to the reef	30, 40, 50, 60
Visability	The average water column visability, measured in feet, surrounding the reef	25, 50, 75, 100
Charter Boat Trip Cost	Charter boat trip fee (not including gear costs or crew tips)	$50, $100, $150, $200

Table 6. Revealed Preference Choices

Number of trips to the USS Vandenberg over the Past 5 Years	**Frequency**	**Percent**	**Cumulative**
0	181	84.6	84.6
1	17	7.9	92.5
2	9	4.2	96.7
3	3	1.4	98.1
4	1	0.5	98.6
10	2	0.9	99.5
50	1	0.5	100.0
Number of trips to the Spiegel Grove over the Past 5 Years	**Frequency**	**Percent**	**Cumulative**
0	170	79.4	79.4
1	21	9.8	89.3
2	9	4.2	93.5
3	3	1.4	94.9
4	3	1.4	96.3
5	1	0.5	96.7
6	1	0.5	97.2
10	3	1.4	98.6
15	1	0.5	99.1
20	1	0.5	99.5
75	1	0.5	100.0

Table 7. Revealed Preference Choices

Revealed Preference Choices	Frequency	Percent
10	206	96.3
11	1	0.5
15	2	0.9
20	1	0.5
25	2	0.9
55	1	0.5
80	1	0.5

Table 8. Separate Revealed and Stated Preference Models

	ECL: Base RP Model		MXL: Base SP Model		MXL: ANA SP Model	
Variable	Mean (SE)	SD (SE)	Mean (SE)	SD (SE)	Mean (SE)	SD (SE)
Opt Out	0.000	-4.01569*** (0.3451)	-5.69920*** (1.19399)	1.15653 (1.04198)	-5.88163*** (1.21439)	.92326 (0.75053)
Artificial Reef: GOLDEN			-.29453* (0.16667)		-.29486* (0.16851)	
Artificial Reef: WRIGHT			-.75302 (0.63138)		-.72292 (0.64244)	
Artificial Reef: SEALIFT			-.56572 (0.44699)		-.55879 (0.45185)	
Artificial Reef: FREEDOM			-1.20414*** (0.32467)		-1.19499*** (0.32795)	
Depth to Reef			-.02597*** (0.00382)	.02296*** (0.00325)	-.02681*** (0.00390)	.02376*** (0.00337)
Time to Reef			-.00898 (0.01488)	.03495*** (0.01207)	-.00984 (0.01502)	.03907*** (0.01021)
Visibility at Reef			.02306*** (0.00507)	.00984 (0.00748)	.02335*** (0.00516)	.01145* (0.00623)
FEE	-0.02491*** (0.00228)		-0.00633** (0.00268)			
FEE (Attended)					-.00816*** (0.00281)	
FEE (Non-Attended)					-.00277 (0.00303)	
TC_OC	-0.00430*** (0.00044)					
Log likelihood function	-860.28549		-680.59958		-677.19025	
McFadden Pseudo R-squared	0.4617825		0.2762752		0.2799006	
Chi Square	1476.22383		519.62507		526.44375	
AIC/n	0.749		1.621		1.615	
n (number of observations)	2306		856		856	
k (number of parameters)	3		13		14	

Table 9. Revealed and Stated Preference Models

Variable	GMXL: Base RPSP Model Mean (SE)	SD (SE)	GMXL: ANA RPSP Model Mean (SE)	SD (SE)
Opt Out	-8.29353*** (0.98904)	.83499 (0.56772)	-8.04210*** (1.15063)	.99554 (0.79810)
Artificial Reef: GOLDEN	-.28737* (0.17231)		-.32836* (0.17790)	
Artificial Reef: WRIGHT	1.02547** (0.51991)		.62147 (0.56167)	
Artificial Reef: SEALIFT	.53106 (0.37240)		.31651 (0.38243)	
Artificial Reef: FREEDOM	-.60872** (0.28301)		-.68392** (0.29847)	
Depth to Reef	-.03401*** (0.00356)	.02436*** (0.00258)	-.03305*** (0.00410)	.02328*** (0.00286)
Time to Reef	-.03820*** (0.01359)	.03434*** (0.00719)	-.03495** (0.01404)	.03278*** (0.01240)
Visibility at Reef	.01278*** (0.00436)	.00547 (0.00734)	.01650*** (0.00473)	.01666*** (0.00472)
FEE	-.01458*** (0.00203)			
FEE (Attended)			-.01516*** (0.00231)	
FEE (Non-Attended)			-.00779*** (0.00290)	
TC_OC	-.04771*** (0.00264)	.02111*** (0.00209)	-.05322*** (0.00190)	.03306*** (0.00067)
Tau	1		1	
Tau (Stated Preference = 1)	-1.82270*** (0.57929)		-1.66552*** (0.55555)	
Gamma	.05999** (0.02804)		.01895 (0.02432)	
Sigma	.98576 (0.98559)		.98571 (0.98697)	
Log likelihood function	-1127.35232		-1116.98621	
McFadden Pseudo R-squared	0.6754711		0.6784552	
Chi Square	4692.91948		4713.6517	
AIC/n	0.724		0.718	
n (number of observations)	3162		3162	
k (number of parameters)	17		18	

Table 10. Willingness to Pay for Artificial Reef Diving Attributes [90% Confidence Interval] (95% Confidence Interval)

	Attended Attributes			Non-Attended Attributes		
Model	Depth to Reef	Time to Reef	Visibility at Reef	Depth to Reef	Time to Reef	Visibility at Reef
SP (Base)	**-$4.10 [-$6.47, -$1.74] (-$6.92, -$1.29)**	-$1.42 [-$4.62, $1.78] (-$5.23, $2.39)	*$3.65 [$0.14, $7.15] (-$0.53, $7.82)*			
SP (ANA)	**-$3.29 [-$4.79, -$1.78] (-$5.08, -$1.50)**	-$1.21 [-$3.79, $1.37] (-$4.28, $1.87)	**$2.86 [$0.49, $5.24] ($0.03, $5.69)**	-$9.68 [-$26.11, $6.75] (-$29.26, $9.90)	-$3.55 [-$10.36, $3.25] (-$11.66, $4.55)	$8.43 [-$8.69, $25.55] (-$11.96, $28.83)
RPSP (Base)	**-$2.33 [-$2.78, -$1.89] (-$2.86, -$1.80)**	**-$2.62 [-$3.82, -$1.42] (-$4.05, -$1.18)**	**$0.88 [$0.26, $1.49] ($0.14, $1.61)**			
RPSP (ANA)	**-$2.18 [-$2.57, -$1.79] (-$2.65, -$1.71)**	**-$2.30 [-$3.52, -$1.09] (-$3.75, -$0.86)**	**$1.09 [$0.42, $1.76] ($0.29, $1.88)**	-$4.24 [-$6.53, -$1.95] (-$6.97, -$1.51)	-$4.48 [-$7.14, -$1.83] (-$7.65, -$1.32)	*$2.12 [$0.17, $4.06] (-$0.20, $4.44)*