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Using choice models to inform large marine protected area design☆

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ABSTRACT

During the last decade a number of Large Marine Protected Areas (LMPAs) – marine protected areas that exceed a minimum size threshold and are often in offshore or open ocean waters – have been designated in an effort to meet marine conservation objectives. Research on the human dimensions of LMPAs is limited, though comprehensive policy analysis requires an understanding of the full range of social, cultural and economic benefits associated with LMPA designation. This paper addresses this need by employing a stated preference choice experiment survey of U.S. west coast households to examine public preferences for different protected area designs sited off the U.S. west coast. Using data from over 3000 randomly selected households in California, Oregon, and Washington we estimate choice models and calculate economic values for a suite of LMPAs that vary in size and in the types of restrictions within area boundaries. Results show that the LMPA size yielding the highest value is ~15.6% of the west coast Federal waters. Results also underscore the importance of restriction type, as there are considerably different threshold sizes above which diminishing returns and negative economic values are derived from no-access reserves, no-take, and multiple-use designations. While the value of any specific configuration can be estimated using the model, results offer insight on optimal use designations from a public perspective for small (< 2.5% of west coast Federal waters), medium (2.5%–~10%) and large (> 10%) LMPAs sited off the U.S. west coast.

1. Introduction

Over the last two decades the establishment of Marine Protected Areas (MPAs) has become a high profile strategy for marine conservation. This is exemplified by the increasing number of MPA designations as well as international doctrine such as Target 11 of the 2010 Aichi Biodiversity Targets under the United Nations Convention on Biological Diversity, which aims to protect more than 10% of coastal and marine areas globally by 2020. Studies demonstrating the myriad benefits provided by MPAs, including ecological [23], economic [4], and social [5] have incentivized governments to designate MPAs in coastal and offshore marine waters, controversy notwithstanding. In Australia for example, there are over 200 MPAs in coastal and marine waters, covering about 10% of Australia's exclusive economic zone (EEZ) [12]. In Namibia nearly one million hectares of marine area and island outcrops are protected via the Namibian Islands Marine Protected Area. In the United States the establishment of four protected marine monuments increased the area of U.S. managed MPAs by about 400% [25]. These marine monuments (Papahanaumokuakea Northwest Hawaiian Islands, Marianas Trench, Pacific Remote Islands, Rose Atoll National Monuments), established between 2006 and 2009, are examples of a growing number of Large Marine Protected Areas (LMPAs), defined here as areas larger than 30,000 km^2 (based on the threshold established by [6]; see [27,28], or [15] for various LMPA definitions). Australia's Great Barrier Reef Marine Park, established in 1971, is generally considered to be the first LMPA; since then approximately 24 additional LMPAs have been designated or are in the process of designation, most within the last 10 years [15]. Some studies suggest that the designation of LMPAs may render Target 11 attainable by 2025 – without them it may take 20 years longer [28].

LMPAs have been designated for many of the same inherent reasons as smaller-sized MPAs – protecting ecological and cultural resources, biodiversity conservation, rebuilding depleted stocks, and promoting sustainable development. While some authors argue that LMPAs are simply lines on a map with limited enforceability and of questionable value for biodiversity and fisheries protection [7], other researchers have argued that smaller MPAs need to be 'scaled up' to fully attain the intended ecological benefits [9]. Wilhelm et al. [32] notes that many LMPAs are large enough to encompass and connect ecosystems, protect portions of habitat for highly migratory species, and protect deep-sea or

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open ocean habitats that aren't often protected by smaller coastal or inshore MPAs. In addition, some authors suggest that LMPAs may be politically easier to establish than smaller near-shore MPAs [2] and that, per unit area, LMPAs may be less costly to establish than smaller MPAs [24]. Though empirical evidence is somewhat limited, these claims are likely bolstered by the perception of fewer social and political repercussions associated with imposing restrictions in offshore open ocean areas.

A number of studies have asserted the economic benefits generated from LMPAs; some of the more frequently cited are those derived from Australia's Great Barrier Reef Marine Park. The economic value of activities such as recreational fishing, scuba diving, and snorkeling on the Great Barrier Reef are well documented [8,26]. However, these types of use values may not always be applicable for offshore open ocean sites, where LMPAs are often designated. For these areas economic value may be derived from things such as preserving ocean wilderness even if the area is rarely visited by people, protecting entire ecosystems or large areas of critical marine habitat, or protecting an area for future generations to use. These types of values are sometimes referred to as non-consumptive use values or non-use values. An emerging body of literature has examined these types of values for protecting areas of the ocean and/or preferences for the types of restrictions within these areas. While the few studies undertaken have not explicitly referenced the term LMPA, three of the four studies discussed below focus on large offshore areas that meet the LMPA criteria defined above.

Wattage et al. [31] use a choice experiment survey to examine the economic value of protecting deep-sea corals in Irish waters. The corals have limited scope for recreation or tourism [31], thus the authors focus on estimating the non-use value of protecting varying proportions of the total amount of deep-sea corals by restricting commercial fishing. Their results suggest that most survey respondents prefer expanding the current protected area (approximately 2500 km^2) to include all deep-sea corals that are thought to exist in Irish waters – an area substantially larger than the status quo. Results also suggest that respondents prefer to ban all trawling in deep-sea coral areas rather than banning commercial fishing entirely. While the authors do not formally compute willingness-to-pay (WTP), a measure of economic value, their results imply, at least qualitatively, that respondents were willing to pay a small personal tax to protect all deep sea corals in Irish waters. Turpie et al. [29] estimate the non-use value of three MPAs off the coast of South Africa using a contingent valuation survey. They ask survey respondents about different scenarios related to the MPAs, including an elimination of all three MPAs, increasing the total amount of area that is protected and restricting fishing, and allowing some fishing in one of the protected areas that currently prohibits fishing. Their results suggest that the value of increasing the total amount of protected area from the status quo and restricting fishing is about US$ 4.8 million, and that eliminating the MPAs entirely results in a loss of about US$ 27.6 million. Allowing some fishing in areas where it is currently prohibited resulted in a smaller loss of about US$ 4.4 million. Wallmo and Edwards [30] use a choice experiment survey to estimate the value of "habitat areas of particular concern" (HAPCs), defined as habitats that are especially important ecologically or particularly vulnerable to degradation, in the northeastern U.S. EEZ. They found that the value of protecting all proposed HAPCs, which would increase the amount of federally protected area in the northeastern U.S. EEZ by about 4.2%, ranged from about US$ 23 per household to US$ 106 per household in the northeast U.S., depending on what types of restrictions were in place. Their results also suggest that there was considerable preference heterogeneity among respondents, and the protection of HAPCs generated negative value for some individuals. Finally, Gillespie and Bennett [12] estimate the value of establishing a network of MPAs covering up to 30% of the south-west marine region in Australia. Their results suggest that Australian households would pay about AU$100 to establish an MPA network protecting 30% of south-western Australian waters, though WTP was not affected by different sized networks (10%, 20%, or 30% of south-western waters), indicating insensitivity to scope.

The above studies imply that individuals derive values from LMPAs even if they never see or visit them; they also offer some evidence that preferences can vary for both the size and the restrictions that will be established for these areas. These preferences ultimately will determine an individual's willingness-to-pay for LMPAs, and provide one measure of their economic benefits. This suggests that an understanding of the relationship between LMPA configurations (in terms of size and restrictions) and economic value can be extremely useful for LMPA planning and decision-making. Gruby et al. [15] underscore this point in developing an LMPA social science research agenda that calls for an examination of the "full range, magnitude, and distribution of actual and perceived social, cultural, political, and economic benefits associated with LMPAs". This paper directly addresses their research agenda by estimating economic values, including non-use values, for LMPA configurations in U.S. Federal Waters (referring only to waters between 3 and 200 miles offshore, and not including inshore/coastal State waters) off the coasts of California, Oregon, and Washington, referred to in this paper as west coast Federal waters. The research extends the current literature on the human dimensions of LMPAs by adding an economic benefit estimate for large protected areas off the U.S. west coast. In addition the results should be of high interest for managers and decision-makers as they identify (a) the effect of LMPA size on value; (b) the effect of varying levels of restrictions within LMPAs on value; and (c) specific size/restriction combinations that maximize the economic benefits of offshore LMPAs for U.S. west coast households – three policy-relevant aspects of LMPAs that are often contested but have limited empirical evidence on which to base decisions.

2. Methods

2.1. General overview

This research employs a stated preference choice experiment (SPCE), a specific type of economic valuation technique for non-market goods and services. There are relatively limited applications of SPCE to marine protected area valuation [13], though Glenn et al. [13] suggest that the multi-attribute approach of SPCE can facilitate a more in-depth analysis of protected areas than other types of non-market valuation methods (i.e. contingent valuation). They provide a summary of these advantages over the more traditional contingent valuation method; full expositions on SPCE can be found in Adamowicz et al. [1]. A general overview of the method followed by a more detailed description as it applies to this research is presented below.

SPCE are grounded in Lancastrian consumer theory [21], which specifies that an individual's utility for a good is a function of the good's attributes. For example, one's utility for a house may depend on attributes such as the number of bedrooms, bathrooms, location, price, etc. For environmental applications, the good is typically a non-market good – i.e. not bought or sold in traditional markets – characterized by attributes of policy or management interest. As non-market goods are typically unfamiliar to consumers, a survey is used to provide basic information about the attributes of the good. A range of numeric or categorical levels is specified for each attribute, and experimental design plans are used to generate different combinations of attribute levels. Survey respondents are shown choice task questions that contain two or more alternatives (different bundles of attribute levels), and are asked to indicate which is their most (and sometimes least) preferred.

The survey described potential protected areas sited in Federal waters off the U.S. west coast in terms of the following attributes and attribute levels:

- The percent of west coast Federal waters that would be protected as an ecological reserve, with no human activities or access permitted within the boundaries (0.05%, 1.0%, 2.0%, 3.0%, 5.0%).

- The percent of west coast Federal waters that would be protected as a 'no take' zone, allowing access to the site but prohibiting all extractive activities (0.05%, 2.0%, 5.0%, 8.0%, 10.0%).
- The percent of west coast Federal waters that would be protected as a 'multiple use' zone, allowing commercial and recreational fishing, tourism if applicable, and scientific research – all other extractive activities (e.g. mining, oil exploration) are prohibited (2.95%, 5.0%, 8.0%, 10.0%, 15.0%).
- The total percent of west coast Federal waters that would be protected (a summation of the first three attributes).
- The cost to households in California, Oregon, and Washington to offset research, monitoring, and enforcement within the area and to help offset costs to industries affected by any new restrictions until they can adjust. The cost was incurred every year for three years as an addition to the household's federal income tax ($10, $20, $50, $75, $100, $125).

2.2. Experimental design

The experimental design plan was computed using the SAS experimental design and choice modeling macros [19]. The final design plan eliminated unrealistic scenarios where, for example, an alternative with a large percent of area designated as an ecological reserve cost less than an alternative with the same size or smaller area designated as multiple-use (as one might expect a larger area to be more costly to monitor and offset industry losses). The final design consisted of 150 alternative scenarios which were then paired and blocked into choice task questions that contained three alternatives: a status quo and two alternatives that increased the amount of at least one type of protected area. Alternatives were blocked into choice task questions using the SAS choice efficiency macros. This design resulted in 50 different survey versions, with three choice task questions per version and two alternatives plus the status quo per question. Versions were randomly distributed among randomly selected households in California, Oregon, and Washington.

2.3. Survey development and implementation

The survey instrument was developed using qualitative research including focus groups and cognitive interviews. The final instrument consisted of 6 sections and 55 questions. Section 1 discussed marine protected areas in general and provided respondents with a map of west coast federal waters. Section 2 provided background information about the primary objectives of protected areas in west coast federal waters, including conservation and restoration of biodiversity, setting aside marine wilderness areas, and providing opportunities to experience these ocean areas now and into the future. Section 3 described the potential benefits and costs of protected areas and how these may vary with size. Section 4 provided information on the existing sizes and types of protected areas found in west coast Federal waters, including the status quo of each permanently protected area type described above (no-access ecological reserve 0%; no-take 0.05%; multiple use 2.95%). Section 5 contained the choice experiment, which consisted of three choice task questions, each containing three alternatives (see Fig. 1). Section 6 consisted of questions related to a range of ocean and environmental behaviors and attitudes.

The survey was pretested twice using a random sample of California, Oregon, and Washington households from a web-enabled panel [11]. The first pretest was implemented in August 2012 with a sample of 2308 households (66.7% completion rate). The second pretest was implemented in November 2012 with a sample of 1268 households (64.9% completion rate). The main survey implementation began in December 2012 with random sample of 5349 households (47% completion rate). All surveys were implemented online using the online survey platform maintained by the GfK Group. The final dataset used for this analysis included observations from the second pretest and the main survey (n = 3354).

MPAs West Coast Federal Waters	Option 1 (Current Status)	Option 2	Option 3
% of West Coast Federal Waters designated No-Access MPAs	0%	3%	1%
% of West Coast Federal Waters designated No-Take MPAs	0.05%	0.05%	1%
% of West Coast Federal Waters designated Multiple Use MPAs	2.95%	2.95%	4%
Total amount of West Coast Federal Waters designated as a Marine Protected Area	3%	6%	6%
Cost to your Household …This cost will be added to your household's Federal Income Tax every year for three years	$0	$15	$10
Q6. Which option do you most prefer for West Coast Federal Waters? (check only one box)	Option 1 ❐	Option 2 ❐	Option 3 ❐

Fig. 1. Example of choice task question.

2.4. Modeling framework and estimation

Random utility theory provides the modeling framework for this research. The theory specifies that utility (U) for a good consists of a systematic, known component (V) and a random component (ε). In this case, the good in question is an MPA, and the utility that individual i receives from MPA alternative a can be expressed as

$$U_{ia} = V_{ia} + \varepsilon_{ia} \tag{1}$$

where U_{ia} is the unobservable utility that i associates with a, V_{ia} is the quantifiable, known portion of utility, and ε_{ia} is the random, unobservable effects associated with a for individual i. Alternative a can be decomposed into its specific attributes of amount of MPA designated as multiple-use, no-take, and no-access; the systematic component of utility V_{ia} is then

$$V_{ia} = \beta X_{ia} \tag{2}$$

where X_{ia} is a vector of attributes and the associated levels for MPA alternative a and β are the attribute coefficients. Substituting the expression for V_{ia}, the utility function can be expressed as

$$U_{ia} = \beta X_{ia} + \varepsilon_{ia} \tag{3}$$

Under the assumption that individuals are utility maximizers, the probability that an individual i will choose MPA alternative a from a set of C alternatives is equal to the probability that the utility derived from a is greater than the utility derived from any other alternative in the choice set C, expressed as

$$\begin{aligned} \Pr(i\ chooses\ a\ from\ C) &= \Pr(U_{ia} > U_{ij}) for\ all\ j \in C \\ &= \Pr(V_{ia} + \varepsilon_{ia} > V_{ij} + \varepsilon_{ij}) for\ all\ j \in C \\ &= \Pr(\beta X_{ia} + \varepsilon_{ia} > \beta X_{ij} + \varepsilon_{ij}) for\ all\ j \in C \end{aligned} \tag{4}$$

Assuming a type I extreme value distribution for the error component (a common assumption for discrete choice models; [22]), (4) is operationalized as

$$\Pr(i\ chooses\ a) = \exp\ (\beta X_{ia}) / \sum_{j=1}^{J} \exp(\beta X_{ij}) \tag{5}$$

If choice observations are ordered so that the first n_1 individuals chose alternative a, the next n_2 individuals chose alternative b, and so on for all j elements of the choice set C, the likelihood function for (5) can be written as

$$L = \prod_{i=1}^{n1} P_{1i} \sum_{i=nl+i}^{nl+n2} P_{2i}\ldots\ldots \prod_{i=I-nj+1}^{I} P_{ji} \tag{6}$$

which simplifies to

$$L = \prod_{i=1}^{I} * \prod_{j=1}^{J} lnP_{ij}^{fij} \tag{7}$$

Defining a dummy variable f_{ij}, where $f_{ij} = 1$ when alternative j is chosen and $f_{ij} = 0$ otherwise, the function can be can be written as

$$L^* = \sum_{i=1}^{I} \sum_{j=1}^{J} f_{ij} lnP_{ij} \tag{8}$$

By replacing the term P_{ij} with (5), the only unknown parameters are the elements of β, which are estimated through maximum likelihood techniques.

The conditional logit model above is a popular choice for modeling discrete choice data, and when data are rich and disaggregate the model is often robust (in terms of prediction success) to the implicit behavioral assumptions arising from the chosen error distribution [22]. The model is limited, however, in accommodating preference heterogeneity among individuals, leading to alternative specifications such as the random parameters logit and latent class logit [14] to address this need. This research adopts the random parameters logit model, as focus groups suggested that preferences for MPAs were not homogenous, and in fact could be utility-decreasing for some individuals.

As in the conditional logit model the unobserved component utility is assumed to be distributed as a type I extreme value distribution. However, the random parameters logit model assumes that one or more of the attribute parameters are distributed continuously over the population instead of being fixed (as in the conditional logit). Thus, the probabilities of selecting an option j in the RPL model (π_j) are evaluated over the parameter distributions. They can be expressed as

$$\Pr(choose\ j) = \pi_j = \int \{\exp\ (V_j(\beta))/ \sum_k \exp\ (V_k(\beta))\} f(\beta) d\beta \tag{9}$$

for all j,k = Options A, B, and C and where V_j is the utility associated with the jth option and $f(\beta)$ is the probability distribution of the utility parameters β. These probabilities are approximated through simulation as follows: R draws of β are taken from $f(\beta)$, and the conditional choice probabilities are evaluated at each draw. The simulated probability of choosing the jth alternative (π_j^s) is the mean over the R draws

$$\pi_j^s = R^{-1} \sum_{r-1}^{R} \exp(V_j(\beta^y))/ \sum_k \exp\ (V_k(\beta^y)) \tag{10}$$

where β^r is the rth coefficient vector draw from the mixing distribution, $f(\beta)$, assumed to be multivariate normal in this application.

Because each respondent was faced with three choice questions in the survey, the joint probability of observing the sequence of choices an individual makes is modeled as the product of individual choice probabilities

$$\Pr[j,\ k,\ l] = \pi_j^s * \pi_k^s * \pi_l^s \tag{11}$$

where j is selected in the first question, k is selected in the second question, and l is selected in the third.

3. Results

3.1. Descriptive statistics

Respondent demographic characteristics were provided by the GfK Group. The average age of respondents was 51 years old with 8–20% of respondents falling in each of the following age categories: 18–24 years, 25–34 years, 35–44 years, 45–54 years, 55–64 years, 65–74 years, and 75 and over. Most respondents had completed a bachelor's degree or higher (44%) or some college (40%). Annual household income distribution of respondents was as follows: $24,999 or less (19%) $25,000–$49,999 (25%), $50,000–$99,999 (35%), and $100,000 or more (21%).

Respondents were asked a number of behavioral questions to help determine their participation level in marine-based activities. Overall about 20% of respondents stated they had participated in some form of ocean-based recreation, including fishing. A small proportion (1.3%) of respondents indicated that they or someone in their family fished commercially in west coast Federal waters and less than 1% stated that their own job was directly tied to west coast Federal waters. Frequency of participation in marine-based activities, including (a) viewing ocean features and wildlife; (b) fishing/shellfishing; (c) boating/kayaking/canoeing; (d) swimming/surfing/diving; and (e) tidepooling/sunbathing was relatively low, with less than 5% of respondents stating they participate at least several times per month, and between 20% and 30% stating they participate but not on a regular basis.

The survey dataset contains 3354 observations. In the survey each respondent faced three separate choice tasks, resulting in 10,062 choice task questions (3 × 3354). Less than 1% (52) of respondents left all three choice task questions blank; these respondents were removed from the dataset for the model estimation. The majority of respondents were able to make a choice among the three alternatives presented in each choice task question, as item non-response to the first, second, and third choice tasks was 2.5%, 2.5%, and 3.3%, respectively. The status quo alternative was selected by 39.8%, 39.5%, and 41.0% of respondents in the first, second, and third choice task, respectively. Respondents also varied their choices in most cases, as only 9.6% of respondents chose the status quo in all three choice tasks, 2% always chose alternative 2%, and 1.7% always chose alternative 3.

3.2. Model results

The econometric model allows for diminishing marginal utility for each size/restriction combination by specifying a quadratic functional form where X_1 represents the percentage of federal waters designated as an ecological reserve with no access, X_2 is the percentage of federal waters designated as no-take zone, X_3 is the percentage of federal waters designated as a multiple-use zone allowing commercial and recreational fishing, tourism if applicable, and scientific research, X_4 is the cost associated with the MPA, and ε is the error term.

$$V = \beta_1 X_1 + \beta_2 X_1^2 + \beta_3 X_2 + \beta_4 X_2^2 + \beta_5 X_3 + \beta_6 X_3^2 + \beta_7 X_4 + \varepsilon \tag{12}$$

As described in the Methods, a random parameters model is specified to allow for heterogeneity among respondents, and all parameters with the exception of cost were modeled as random. Model results are presented in Table 1.

Results show that all of the size/restriction attributes in the utility function are highly significant ($p < 0.01$). The positive and significant attribute parameter signs on each linear attribute (except cost) imply that designating federal waters as a no-access ecological reserve, no-take and multiple use zones is utility increasing, though diminishing marginal utility is shown via the negative and significant sign on each non-linear attribute parameter. The cost parameter is negative and significant ($p < 0.01$), as expected. The standard deviations for each parameter, also presented in Table 1, suggest that for the linear attributes – % of ecological reserve, % of no-take federal waters, and % of multiple use federal waters – there is significant heterogeneity among respondents ($p < 0.01$). However, the insignificance of the standard deviation parameters for the non-linear size/restriction attributes suggests that preferences are homogenous for diminishing marginal utility.

The magnitudes of the linear parameters suggest that preferences are strongest for designating federal waters as no-access ecological

Table 1
Choice model results.

Attribute	Parameter estimate	Z statistic
Random parameters		
No-access**	.57632	11.41
No-access^2**	−.11720	−11.58
No-take**	.15999	6.26
No-take^2**	−.01625	−6.29
Multiple use**	.17295	6.38
Multiple use^2**	−.01051	−6.59
Non-random parameters		
Cost**	−.02295	−32.56
Standard deviation parameters		
No-access**	.66837	19.37
No-access^2	.00164	0.16
No-take**	.32913	22.25
No-take^2	.00222	1.05
Multiple use**	.25310	17.06
Multiple use^2	.00029	0.27

** Parameters significant at $p < 0.01$.

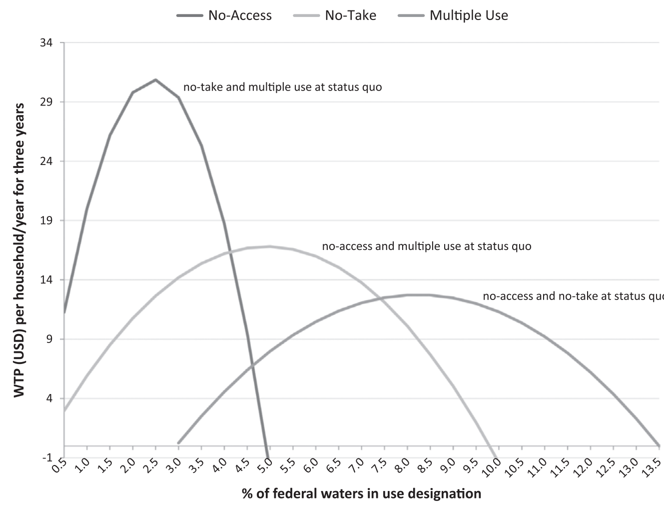

Fig. 2. Changes in WTP with respect to size.

reserves; however, because the model specification suggests (significant) concavity for each size/restriction combination the optimal (maximum) size for federal waters designated for each restriction type is calculated by solving the first order conditions for a specific use type, holding the other two use types constant. This results in the following optimal designations:

- 2.5% of federal waters designated as no-access
- 4.9% of federal waters designated as no-take
- 8.2% of federal waters designated as multiple-use.

3.3. Willingness-to-pay

The economic value (WTP) of designating different protected area configurations (i.e. designating federal waters as protected areas with different restrictions in place) is calculated using the standard formula for estimating compensating variation [16]

$$CV_i = WTP_i = \frac{1}{\beta_p}\ln\left(\sum_i expV_i^1 \sum_i \exp V_i^0\right) \tag{13}$$

where V_i^0 is the utility derived from the initial state, the status quo, and V_i^1 is the utility associated with an alternative state. Using this formula the values for a variety of configurations can be calculated. WTP and 95% confidence intervals [20] for the optimal amount of area in a restriction type (holding other restriction types constant) are as follows: $30.86 (24.73–37.00) for 2.5% of area designated as no-access; $16.81 (10.90–22.73) for 4.9% of area designated as no-take; and $12.75 (7.63–7.86) for 8.2% of area designated as multiple use. All values are expressed as west coast household (California, Oregon, and Washington) WTP per year for three years. The functional relationship between protected area size and restriction type is shown in Fig. 2. Though the optimal no-access designation yields the highest WTP, Fig. 2 shows that the economic value of no-access areas decreases sharply over a smaller range than no-take and multiple-use designations.

4. Discussion

The Federal waters off the U.S. west coast is about 825,549 km^2 (this figure excludes waters off of Alaska and Hawaii), and 30,000 km^2 is approximately 3.6% of this area. Therefore most of the size ranges discussed below can be considered an LMPA using the size criteria defined previously. Non-use value is interpreted as values obtained through designating no-access reserves, as the other two restriction types – no-take and multiple-use – would theoretically not constitute a non-use value even though the areas are in offshore waters. Though the optimal no-access designation yields the highest WTP, their value decreases sharply over a smaller range than no-take and multiple-use designations (see Fig. 2). Assuming that an area has homogenous restrictions within the boundaries (i.e. designated only as no-access, no-take, or multiple-use), several key points emerge from Fig. 2:

- Designating more than approximately 4.8% of the west coast Federal waters as no-access yields disutility (negative economic value). The same is true for any amount of no-take over 9.75% and multiple-use over 13.5%.
- Areas whose size is less than about 4.2% of the west coast Federal waters will yield the highest value designated as no-access.
- Areas between about 4.2% and 7.5% of the west coast Federal waters will yield the highest value if designated as no-take.
- Areas larger than about 7.5% will yield the highest value if designated as multiple-use.

When considering protected areas that include a mix of restrictions, increasing the amount of federal waters in each restriction type up to their maximum amounts – for a total of 15.6% of the west coast Federal waters – provides the largest welfare gain, at approximately $60.42 per household per year for three years. Other combinations will yield lower but still positive economic value to the public. For example, a large area whose total size is 20% of federal waters is valued at $9.87 per household per year for three years when the restriction type is split evenly between no-take and multiple-use. However, moving just 1% of waters from a no-take to a no-access designation increases the value to $36.36. Acknowledging that policy and politics will generally influence both the size and type of restrictions in protected areas, the value (and 95% confidence interval) of different configurations of protected areas of three different total sizes – 5%, 10%, and 15% of federal waters – are shown in Table 2. Table 2 is primarily for illustrative purposes, and although in principal the model can generate values for any type of configuration, values for configurations considerably larger (or smaller) than those generated from the experimental design should be treated with caution. Values in Table 2 are expressed in household WTP per year for three years.

The results suggest that protected areas that ban large-scale extractive industries including mining and oil exploration can generate positive economic benefits for areas as large as 20% of the west coast Federal waters, though the largest economic benefits come from designating slightly less area. Results also demonstrate that the type of restrictions within the protected area matters significantly, as negative economic value (disutility) stems from setting aside more than 4.8% of

Table 2
Value of multiple use-type designations.

Total size (% of federal waters)	No-access (% of federal waters)	No-take (% of federal waters)	Multiple use (% of federal waters)	Value
5%	3	1	1	26.13 (16.00–32.25)
	2	2	1	29.40 (21.92–36.86)
	1	1	3	26.16 (22.80–29.52)
10%	3	4	3	45.82 (38.64–53.02)
	2	3	5	51.98 (46.59–57.37)
	1	5	4	41.39 (35.93–46.84)
15%	3	10	2	22.94 (13.49–32.39)
	2	3	10	55.29 (49.45–61.15)
	1	7	7	45.82 (39.83–51.81)

waters as a no-access reserve, while no-take and multiple-use designations can be considerably larger without incurring disutility. These guidelines are based on average values; it should be noted that the choice model results show significant preference heterogeneity for the linear attributes that represent restriction type. Therefore while a designation may be utility-increasing on average, there may be individuals who experience disutility from the same designation, indicating winners and losers from a policy.

A formal analysis of respondent heterogeneity (and subsequently winners and losers from a given policy) is beyond the scope of this research, though it should be noted that differences in respondent characteristics such as socio-economic status, spatial location (e.g. proximity to the coast), interaction with and use of marine resources, etc.. may be underlying factors. In particular, some research on spatial heterogeneity has shown that willingness-to-pay may exhibit a distance decay effect where values decrease as the distance between the individual and the good increases, though in many cases the goods are direct use goods such as hiking, fishing, snorkeling, etc. [3,10]. Other studies suggest that for non-use goods, which LMPAs sited offshore may represent, there is no reason to expect a distance decay effect [17]. While the survey data analyzed here is not spatially explicit enough to formally examine distance decay, in general respondents were not heavily engaged in marine recreational activities (see Section 3.1), which may suggest they are either not close to a coastline and/or their direct use of marine resources is infrequent.

Aside from distributional effects, the results presented here can help inform on other political questions that arise in developing LMPA policy, such as how large LMPAs can be without generating disutility, or what size-restriction configurations will maximize economic values. While an array of ecological and socio-political factors must be considered in LMPA policy analysis, results of this research provide the following insight from a public preference perspective:

- When considering protected areas that include a mix of restrictions, increasing the amount of federal waters in each restriction type up to their maximum amounts – for a total of 15.6% of the west coast Federal waters – provides the largest welfare gain
- To generate high economic value designate small no-access protected areas, as costs are likely to be smaller for smaller areas.
  - In small sizes no-access is very valuable – designating 2.5% of federal waters as no-access yields more value than a 5% designation of no-take or multiple use.
- LMPAs ranging from ~ 5% to 7.5% of federal waters should be in a no-take designation.
- To establish larger LMPAs designate the areas as multiple-use.
  - For any area larger than ~ 9.75% of federal waters only a multiple-use designation will be utility-increasing.

This research extends the current literature on the economics of LMPAs and contributes to the social science research agenda set forth in Gruby et al. [15] by estimating economic values for LMPAs sited in the U.S. west coast Federal waters and defining functional relationships between LMPA size, restriction type, and value. Unlike Turpie et al. [29] value estimate(s) from this research are not aggregated across the U.S. west coast population; however, household estimates are firmly within the scope of other studies reporting average household values for LMPAs [12,30]. Further, the WTP estimates derived from this study show sensitivity to scope (i.e. WTP decreases after a certain size), demonstrating consistency with economic theory. While the values presented here represent only one component of the full suite of benefits described by Gruby et al. [15], they offer empirical evidence that people are willing, and even desire, to preserve some areas of the ocean as ecological reserves even if they never see or use them – a measure of non-use value. The findings should be of interest for marine policy, as protected area size and the types of restrictions enacted within their boundaries are often initial considerations for LMPA decision-makers.

While results of this research may, at some level, indicate support of Target 11 by the west coast general public, it should be stressed that the results of this study reflect preferences for LMPA size and use in west coast Federal waters only. As noted above, west coast Federal waters was defined for survey respondents in the Introductory section of the questionnaire, and a map designating State and Federal waters was provided to help them distinguish between the two areas. Information on the status quo amount of Federal waters in each type of protected area (no access ecological reserve, no-take, and multiple use), was also provided. Information concerning protected areas in State waters, including National Marine Sanctuaries located entirely in State waters and jointly managed with the Federal government, was not provided. The provision of information about the goods and services described in stated preference surveys has been shown to affect respondent preferences [18], and the correct amount of information to provide is at best a subjective science. Because many environmental goods are unfamiliar to survey respondents, the information presented in stated preference surveys should be thorough enough to allow respondents to make informed choices without appearing persuasive, biased, or supporting a particular agenda or policy. For this study, status quo information on protected areas was limited to Federal waters for several reasons. First, the environmental good respondents were asked about was specific to Federal waters, and represents a different type of good than a marine protected area located closer to shore. Second, status quo information related to protected areas in State waters is considerably complex, and the types of protected areas vary among California, Oregon, and Washington. Providing the quantity and quality of information necessary to accurately convey the status quo of marine protected areas in each state may have led to survey fatigue and increased item nonresponse and/or incomplete surveys. Third, all three states have designated a considerable amount of State waters and shoreline as some type of protected area, with varying restrictions in place. California, for example, with the passage of the Marine Life Protection Act in 1999, has protected approximately 16% of State waters (California Department of Fish and Wildlife 2017). Providing detailed information on the different types and amounts of protected areas in State waters may have unintentionally biased respondents when making choices about offshore sites.

The values generated here are not net of the financial and opportunity costs associated with designation, costs which may vary considerably. McCrea-Strub et al. [24] examine the establishment costs of protected areas using a dataset of thirteen MPAs and LMPAs and find that larger areas may be less expensive to establish *per unit area*, and large areas with a relatively short establishment period may generate the greatest cost efficiency. Their study, however, does not include opportunity costs, which likely vary greatly depending on the spatial location of the area and the affected industries. Future research estimating financial and opportunity costs as well as the benefits of LMPAs are needed, as are studies that examine the distributional effects of protected area designations. The research presented here provides a building block for such studies, and should serve as an initial step toward a more comprehensive perspective for LMPA policy analysis.

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