Untangling the Recreational Value of Wild and Hatchery Salmon

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Abstract Many Pacific salmon populations have declined to levels that have prompted their listing under the Endangered Species Act. In order to protect these populations and provide harvest opportunities for recreational anglers, the fishery is often managed with separate regulations for wild and hatchery salmon. This article examines how the value of recreational fishing is affected by changes in wild and hatchery salmon regulations and catch rates in the Northwest region of the US. Using a discrete choice experiment, we estimate saltwater fishing trip preferences. We integrate the estimated preferences with auxiliary creel data in order to conduct simulations of willingness to pay that vary in bag limits and catch rates, conditioning on current fishery conditions. We find statistically significant differences between the recreational values for wild and hatchery salmon, and our simulations highlight the fact that these differences depend on baseline levels of catch rates and bag limits.

Key words Discrete choice experiment, Pacific salmon, recreational fishing, hatchery, willingness to pay.

JEL Classification Codes Q26, Q51, Q57.

Introduction

Pacific salmon are highly prized by recreational fishermen in the Northwest region of the US. In saltwater, most fishing effort is devoted to king salmon (Oncorhynchus tshawytscha) and silver salmon (O. kisutch) (PFMC 2011), though pink salmon (O. gorbuscha) provide additional opportunities in odd-numbered years in Washington State. Hatcheries have been used on the Pacific coast to supplement wild salmon production since the late 19th century. As current hatchery production of king and silver salmon exceeds natural production, anglers regularly encounter both wild and hatchery fish (NMFS 2003). Current stocks of most Pacific salmon populations have declined to a small fraction of their historic levels. The magnitude of this population decline has led 28 Evolutionary Significant Units (ESUs)\(^1\) of salmonids in the contiguous US to be listed under the Endangered Species Act (ESA), 23 of which are threatened, and 5 of which are endangered.\(^2\)

The salmon fishery in the Exclusive Economic Zone off the coasts of Washington, Oregon, and California is managed by the Pacific Fishery Management Council (PFMC) with guidance from the Magnuson-Stevens Fishery Conservation and Management Act (MSA 2007). In general, the fishery is managed to achieve spawner-escapement goals,
while allocating the harvest among competing groups (e.g., commercial, recreational, and tribal). Separate regulations for wild and hatchery salmon are often used to manage the two stocks in the recreational fishery. Changes in these regulations, hatchery production, or ecological conditions can affect catch rates, size distributions, and the total mortality of hatchery and wild fish. The MSA requires the PFMC to consider the economic efficiency of management decisions, but the existing economics literature offers little support to aid in this process. In fact, existing economic models have not made a distinction between the recreational values of wild and hatchery salmon, implicitly treating wild and hatchery salmon as perfect substitutes.

The valuation of recreational fishing for salmonids has been widely studied in the US (e.g., Johnson and Adams 1988; Layman, Boyce, and Criddle 1996; Morey, Rowe, and Watson 1993; Rowe et al. 1985) and internationally (e.g., Cameron and James 1985, 1987; Håkansson 2008; Olaussen and Liu 2011). Olaussen and Liu (2011) studied wild and escaped farmed Atlantic salmon (Salmo salar) in a recreational fishing application in Norway; however, recreational anglers and fishery managers may draw a strong distinction between a salmon that escapes from an aquaculture operation and one that is intentionally released from a hatchery to support harvest. A review of the literature yielded only one economic survey that collected data at the level of detail necessary to enable a separate treatment of wild and hatchery salmon, but the data were aggregated during estimation (Cameron and James 1985, 1987). The lack of economic research separating wild and hatchery salmon might come as a surprise considering the amount of attention given to the distinction by biologists, fishery managers, the public, and the media.

The focus of this article is the estimation of angler preferences for wild and hatchery salmon. We test whether anglers exhibit statistically different preferences for wild and hatchery catch. We also test whether anglers show statistically different preferences for catch in excess of the bag limit (catch that must be released), and examine how these preferences vary by fish size (weight). The values we calculate for wild and hatchery salmon are then used to measure the economic effect of competing management scenarios, such as changes in bag limits in the recreational fishery. By using a contemporaneous set of baseline fishery data, we are able to provide model simulations of changes in catch rates and bag limits and avoid the bias that can come about through the use of a more stylized baseline.

In the next section, we discuss the historical background related to wild and hatchery salmon. This is followed by a description of the data sources, including the experimental design for the survey. Next we turn to the econometric modeling framework and willingness to pay (WTP) calculations. Finally, we provide model simulations that illustrate the relative efficiency of competing management scenarios before we conclude.

**Hatchery and Wild Salmon Background**

There is a general lack of consensus regarding the definition of a wild salmon. The Independent Scientific Advisory Board (ISAB) defines wild salmon to be “derived from eggs spawned and incubated in the natural environment” and hatchery salmon to be “derived from eggs spawned and incubated, and then emergent fry reared, usually to the smolt stage, in a hatchery,” regardless of the potential hatchery history of the parents (ISAB 2002, p. 18). In contrast, most grocery stores and restaurants use the term wild to mean anything other than farmed. Thus in most market settings, there is no differentiation between wild and hatchery salmon.

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3 For example, the law states that “conservation and management measures shall, where practicable, consider efficiency in the utilization of fishery resources; except that no such measure shall have economic allocation as its sole purpose” (MSA 2007, 16 U.S.C. § 1851 (a)).
For recreational anglers, the most relevant definition is found in the fishing regulations. The vast majority of salmon reared in hatcheries in Washington and Oregon have their adipose fins clipped (removed) prior to being released. Figure 1 provides an illustration depicting the location of the adipose fin on a wild salmon. Recreational fishing regulations in both states explicitly define a hatchery salmon to have a clipped adipose fin and a wild salmon to have an unclipped adipose fin.

Fin-clipped fish are often referred to as marked. In the case that all hatchery fish have their adipose fin removed, the definition in the fishing regulations is indistinguishable from the ISAB definition provided above. Fishery managers use differential laws regarding the retention of wild and hatchery salmon in what are known as mark-selective fisheries. The marking process used at hatcheries provides salmon fishermen with the means to distinguish wild and hatchery salmon. The consequences for violation of the regulations can be quite severe; take of an ESA-listed fish may lead to fines or even include the confiscation of a boat or vehicle.

On the West Coast of the US, hatcheries have been used for over 100 years to supplement natural production, primarily to enhance harvest in recreational, commercial, and tribal fisheries. The scale of hatchery operations is particularly large in this region; almost 2 billion salmon and steelhead have been released each year since 2000 on the West Coast of the US from Alaska to California, on average (Kostow 2009). Average annual production in the combined areas of Washington, Oregon, Idaho, and California is 25% of this total, with the remaining production coming from private, not-for-profit hatcheries in Alaska. As increasing evidence suggests that hatchery production could be detrimental to the health of wild stocks through either genetic or ecological interactions (e.g., Araki, Cooper, and Blouin 2007; Buhle et al. 2009; Kostow 2009; McClure et al. 2008; Oosterhout et al. 2005), hatchery practices are being reevaluated. In addition, increased hatchery production may lead to increased fishing pressure. Even under mark-selective management, this has the potential to adversely impact wild populations in mixed-stock fisheries if the mortality rate associated with the release of unmarked fish is nonzero (Lawson and Sampson 1996). Indeed, future fishery management may be less reliant on the use of hatchery production to moderate the effects of habitat loss and substitute for declining natural production than it was in the past.

Perhaps more direct and less controversial than a direct change in hatchery production, fishery managers can also adjust daily or seasonal bag limits to affect the total mortality and change the mixture of wild and hatchery salmon being kept by recreational fishermen. Though the ecological effects of changes in hatchery production or regulations are perhaps not fully understood, it is likely that the economic effects of such changes are even less well known.

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4 While we use marked (unmarked) interchangeably with hatchery (wild) in this article, we acknowledge that this relationship is not exact in a biological sense, as some hatchery salmon are left unmarked.
Survey Data

The data we use to estimate angler preferences are the result of two statewide recreational fishing surveys: one in Washington, which we call the Washington Sport Fishing Survey, and one in Oregon, which we call the Oregon Sport Fishing Survey. The surveys were tested extensively with anglers, using a total of 8 focus groups and 56 one-on-one interviews. This pre-testing, in part, helped to ensure the attributes and levels presented in the discrete choice experiment (DCE) were contextually realistic and presented the respondents with no excessive cognitive difficulties.

The two surveys were administered by mail and telephone, following the general procedures suggested by Dillman (2000). Surveys were administered during 2006 and 2007 to approximately 8,000 randomly selected adult anglers in each state who purchased a license that enabled them to fish in saltwater. The nonresident subgroup of the population was oversampled within each state. This stratified random sampling is accounted for through the use of a weighted technique in subsequent estimation.

The full survey protocols included up to six total contacts: an initial telephone survey, a prenotice letter, the first mailing of the survey, a postcard reminder, the second mailing of the survey, and the third mailing of the survey. The primary purpose of the initial telephone survey was to screen out anglers who had not taken a saltwater fishing trip within the last 12 months, as many types of fishing licenses allow both saltwater and freshwater use. The mail surveys achieved response rates of 48% and 51% among saltwater anglers in Washington and Oregon, respectively.

The Washington survey separates the state into two distinct areas: the Inside area and the Ocean area (figure 2), corresponding with Marine Area (MA) 1 through MA 4 in the Washington State fishing regulations and MA 5 through MA 13, respectively. This separation served the primary purpose of adding contextual realism to the DCE questions, as the two areas have significantly different recreational fishing regulations. In the DCE questions for Washington, all choice trips were described as either Inside area or Ocean area trips to ensure a consistent context across respondents. The map in figure 2 shows the marine areas of western Washington, northern Oregon, and the southern edge of Canada, including a portion of Vancouver Island. The lighter (darker) grey shading on the map is what we define to be the Ocean (Inside) area.

Figure 2. Washington Ocean Area and Inside Area
Recreational Value of Wild and Hatchery Salmon

The DCE questions provided respondents with a series of choices among saltwater fishing trips that included the most commonly targeted species in Oregon and Washington: halibut, lingcod, rockfish, king salmon, and silver salmon. In addition, the Washington survey also included pink salmon. Each DCE trip provided a description of catch (by size and species), the daily bag limits, and fishing cost in order to mimic the information typically available to anglers when making choices. The full list of attributes and attribute levels from the experimental design are given in Table 1.

Respondents were asked to fully rank four sets of three choices. Figure 3 includes an example choice set, taken from the Oregon survey, for reference. In addition to ranking the set of three choices (C3 in figure 3), respondents were asked to indicate the number of trips for each choice (C3.2 in figure 3) and categorize the opt-out option from a menu of choices (C3.3 in figure 3). Note that the choice questions depict salmon as either wild or hatchery.

In addition to the survey data described above, we also use a set of creel survey data collected from the recreational fishery during the same time period to simulate changes in fishing regulations and catch rates. The sources and steps used to prepare the creel data for simulations are described in a later section of this article.

Table 1
Experimental Design Attributes and Attribute Levels

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Washington Inside Levels †</th>
<th>Washington Ocean Levels †</th>
<th>Oregon Levels †</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halibut catch: small (15 lb.), medium (25 lb.), and large (50 lb.)</td>
<td>1, 2</td>
<td>1, 2</td>
<td>1, 2</td>
</tr>
<tr>
<td>Halibut limit</td>
<td>1, 2</td>
<td>1, 2</td>
<td>1, 2</td>
</tr>
<tr>
<td>Lingcod catch: small (5 lb.), medium (10 lb.), and large (15 lb.)</td>
<td>1, 2, 3</td>
<td>1, 2, 3</td>
<td>1, 2, 3</td>
</tr>
<tr>
<td>Lingcod limit</td>
<td>1, 2, 3</td>
<td>1, 2, 3</td>
<td>1, 2, 3</td>
</tr>
<tr>
<td>Rockfish catch: small (2 lb.), medium (4 lb.), and large (6 lb.)</td>
<td>1, 2</td>
<td>8, 10, 12</td>
<td>4, 6, 8</td>
</tr>
<tr>
<td>Rockfish limit</td>
<td>1, 2</td>
<td>8, 10, 12</td>
<td>4, 6, 8</td>
</tr>
<tr>
<td>Wild silver catch: small (5 lb.), medium (10 lb.), large (15 lb.)</td>
<td>1, 2, 3</td>
<td>1, 2, 3</td>
<td>1, 2, 3</td>
</tr>
<tr>
<td>Wild silver salmon limit</td>
<td>0, 1, 2</td>
<td>0, 1, 2</td>
<td>0, 1, 2</td>
</tr>
<tr>
<td>Hatchery silver catch: small (5 lb.), medium (10 lb.), and large (15 lb.)</td>
<td>1, 2, 3</td>
<td>1, 2, 3</td>
<td>1, 2, 3</td>
</tr>
<tr>
<td>Silver salmon limit</td>
<td>n/a</td>
<td>n/a</td>
<td>0</td>
</tr>
<tr>
<td>Wild king catch: small (10 lb.), medium (20 lb.), and large (30 lb.)</td>
<td>1, 2, 3</td>
<td>1, 2, 3</td>
<td>1, 2, 3</td>
</tr>
<tr>
<td>Wild king salmon limit</td>
<td>0, 1, 2</td>
<td>0, 1, 2</td>
<td>0, 1, 2</td>
</tr>
<tr>
<td>Hatchery king catch: small (10 lb.), medium (20 lb.), and large (30 lb.)</td>
<td>1, 2, 3</td>
<td>1, 2, 3</td>
<td>1, 2, 3</td>
</tr>
<tr>
<td>King salmon limit</td>
<td>1, 2</td>
<td>1, 2</td>
<td>1, 2</td>
</tr>
<tr>
<td>Pink salmon catch (3 lb.)</td>
<td>2, 4</td>
<td>2, 4</td>
<td>n/a</td>
</tr>
<tr>
<td>Pink salmon limit</td>
<td>2, 4</td>
<td>2, 4</td>
<td>n/a</td>
</tr>
<tr>
<td>Total salmon limit</td>
<td>2, 4</td>
<td>2, 4</td>
<td>2, 4</td>
</tr>
<tr>
<td>Fishing cost</td>
<td>20, 40, 80 †</td>
<td>20, 40, 80 †</td>
<td>20, 40, 80 †</td>
</tr>
</tbody>
</table>

† DCE trip profiles consisted of a subset of all attributes (e.g., a salmon trip did not include bottomfish catch or bag limits) and therefore the full experimental design also included a missing or zero level for each of the attributes listed above with the exception of fishing cost.

‡ Levels shown are for private boat cost. Charter boat cost levels were 85, 125, 175.
Experimental Design

The experimental design was generated in two distinct stages: i) we generated a candidate set consisting of feasible saltwater fishing trips, and ii) we paired members of this candidate set using a computerized search algorithm that attempts to maximize D-efficiency.

The candidate set was constructed from many smaller designs we used as building blocks. This was necessary because the full factorial design, a typical choice in the literature for candidate set, was too large to implement.\(^5\) One building block design was constructed for each type of single-species trip. Additional building block designs

\(^5\) For example, the full \(2^{1\cdot3\cdot4\cdot22}\) factorial for the Oregon portion of the study alone would require \(76,948,221,758,275,584\) unique combinations.
were constructed for each combination of multiple-species trips. Each building block design was created using the methods described in Kuhfeld, Tobias, and Garrat (1994); a computerized search algorithm selected a design that was efficient, but not necessarily orthogonal. Next we appended these building block designs into one large candidate set and eliminated unrealistic trips. The last step in creating the candidate set was to eliminate trips where it was not possible to uniquely identify which salmon would be kept.

We then followed Zwerina, Huber, and Kuhfeld (2005) by using a computerized iterative search algorithm to optimally pair members of this candidate set based on maximizing the D-efficiency of a choice model. Standard discrete choice models require a set of prior expected parameter values to assess the efficiency of a design. Alternatively, prior values can be set to zero when the sign and magnitude of true parameter values are unknown, as was the case in our study. Anderson (2009) has shown when the data generating process is unknown, maximizing the D-efficiency of a choice model with parameter values set to zero still provides more accurate WTP estimates than maximizing the D-efficiency of a linear model.

The final design for each state survey was blocked into 50 sets of four DCE questions. In order to ensure that each respondent received trips representing different types of tradeoffs, we created a blocking variable that was held orthogonal to the types of trips being compared in each choice set. For a more detailed description of the surveys, including the experimental design, see Anderson and Lee (2011).

Modeling Angler Choices

We use McFadden's (1974) random utility model (RUM) to analyze the DCE questions. Utility is taken to be a function of price (Price), a set of indicator variables fully depicting the opt-out (Opt), fish catch (Catch), fish which must be released (Release), and a set of indicator variables that depict general trip types (Type). We can therefore model utility as:

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6 The term combination trip refers to a trip where anglers target or catch more than one of the following: halibut, rockfish, lingcod, silver salmon, and king salmon. We used the Recreational Fisheries Information Network (RecFIN 2006) data from 2000 through 2003 to choose the most important combination trips, which lead to selecting all of the possible bottomfish-bottomfish combination trips and all of the salmon-salmon combination trips, but no salmon-bottomfish combination trips. The last step in creating the candidate set was to eliminate trips where it was not possible to uniquely identify which salmon would be kept.

7 These linear designs were generated in SAS using the %mktex macro. The SAS code is available from the authors upon request.

8 As an example, trips with total salmon catch exceeding six per person per day were found to be unrealistically high through focus group and one-on-one testing with anglers.

9 The uncertainty in determining which salmon would be kept was a result of the salmon regulations used by fishery managers; grouped regulations do not allow for a unique characterization of the salmon which would be kept on a given trip without additional information. As an example, the total salmon limit was problematic when catching both king and silver salmon on the same trip unless one of the more narrowly defined regulations (king salmon limit, wild king salmon limit, silver salmon limit, wild silver salmon limit) had the effect of bringing total salmon catch below the total salmon limit. This deleted subset included roughly 30% of the salmon trips in the candidate set. This last step ensured that we can estimate catch and release separately for all respondents without gathering separate information on preferences for keeping salmon species and sizes.

10 The choice sets were formed by the SAS macro, %choiceeff. The SAS code for this is available from the authors upon request.

11 Each choice set may compare, for example, bottomfishing trips to other bottomfishing trips, bottomfishing trips to salmon fishing trips, or salmon fishing trips to other salmon fishing trips so an indicator variable representing these choices was held orthogonal to the blocking variable. Other variables held orthogonal include indicator variables representing the species present (halibut, rockfish, lingcod, silver salmon, king salmon) and the three-level factor of fishing cost.
\[
U_{ni} = V(Price_{ni}, Opt_{tn}, Catch_{ij}, Release_{ij}, Type_{kl}) + \epsilon_{ni},
\]
(1)

where \( n \) indexes respondent, \( i \) indexes alternative, \( j \) indexes choice set, \( t \) is the index for the opt-out indicator variables, and \( k \) is the index for trip type.

If we make the assumption that utility is additively separable and expand the catch and release variables by the species and sizes allowed for in the experimental design, we have:

\[
U_{ni} = \delta Price_{ni} + \sum_s \alpha_s Opt_{tn} + \sum_t \sum_l \beta_t \text{Catch}_{tsij} + \sum_s \sum_l \gamma_l \text{Release}_{tsij} + \sum_k \theta_k \text{Type}_{kl} + \epsilon_{ni},
\]
(2)

where \( s \) indexes species, and \( l \) indexes sizes (given in pounds in the surveys).

The daily catch, \( \text{Catch} \), is defined as the total number of fish caught. Calculating the release variable, \( \text{Release} \), requires an assumption to be made about angler preferences when DCE questions contain daily catch levels above the legal limit.\(^{12}\) Certain salmon regulations specify a threshold for combined catch of more than one species of salmon, potentially complicating the definition of \( \text{Release} \), as trips may require anglers to make tradeoffs between species. However, as mentioned above, cases in which these inter-species tradeoffs were necessary to identify \( \text{Release} \) were dropped from the experimental design. Therefore, the assumption we make is that keeping a larger fish is preferred to keeping a smaller fish within a given species.\(^{13}\) This is consistent with remarks made by respondents during survey testing, and we believe it to be a reasonable assumption.

We exploit additional information collected by the surveys to model the opt-out in defining the indicators \( \text{Opt} \). Respondents were asked to select whether the opt-out would be a saltwater shore fishing trip (\( \text{Opt}_{shore} \)), a freshwater fishing trip (\( \text{Opt}_{freshwater} \)), a fishing trip in another state (\( \text{Opt}_{otherstate} \)), or something other than fishing (\( \text{Opt}_{nofish} \)). Depending on the choices presented to the respondent in the DCE question for the Washington survey, an Inside Area fishing trip (\( \text{Opt}_{inside} \)) and an Ocean Area fishing trip (\( \text{Opt}_{ocean} \)) were also available. These activity and area-specific constants are used to control for influences like safety and familiarity with a fishing area. This information allows us to more thoroughly model the opt-out alternatives on an individual level. In addition, we allow the set of \( \alpha_s \) to be random in the estimation stage to help ensure that respondent-specific contextual variation in the \( \text{Opt} \) indicators is not confounded with the variables in our experimental design.

The trip type indicators, \( \text{Type}_{tk} \), are included to control for the perceived differences in DCE trips not fully described by \( \text{Catch} \), \( \text{Release} \), and \( \text{Price} \). Across the pair of surveys, there are three areas (Oregon, Washington’s Ocean area, and Washington’s Inside area) and two major species groupings (bottomfish and salmon). The cross product of area by species grouping yields six trip types. In addition, difficulty estimating statistically significant parameters for pink salmon catch and release led us to model pink salmon trips using similar trip type indicators. Therefore, there are eight trip type indicators in total.

\(^{12}\) Note that the DCE questions presented scenarios of catch and bag limits, whereas the econometric model is specified in terms of catch and required release. We recognize that differences in framing have been shown to have significant impacts in some contexts and, therefore, presenting the DCE questions as catch and required release could have yielded results that differ from those presented in this article. However, the surveys mimic the typical information available to anglers when making choices about where and when to fish, and the decision to use catch and required release in the subsequent econometric modeling matches the theoretical papers in the literature.

\(^{13}\) Note that we only know whether a fish could be kept, and not whether it would actually be kept by a given respondent.
In order to allow for non-constant marginal utility of Catch within a species, we expand the specification in equation (2) to allow for a quadratic functional form:

\[ U_{nij} = \delta Price_{nij} + \sum_t \alpha_t Opt_{tij} + \sum_s \sum_t \beta_{ts} Catch_{tsij} + \sum_s \rho_s Catch^2_{sij} + \sum_s \sum_t \gamma_{ts} Release_{tsij} + \sum_k \theta_k Type_{kj} + \epsilon_{nij}. \] (3)

The specification in equation (3), while fully general, requires the estimation of a very large number of parameters. A more parsimonious specification aggregates the number of fish that must be released by weight (pounds), requiring us to make the assumption that anglers do not care whether, for example, 20 pounds of fish released come from one or two fish. This is given by:

\[ U_{nij} = \delta Price_{nij} + \sum_t \alpha_t Opt_{tij} + \sum_t \sum_s \beta_{ts} Catch_{tsij} + \sum_s \rho_s Catch^2_{sij} + \sum_s \gamma_s LbsRelease_{sij} + \sum_k \theta_k Type_{kj} + \epsilon_{nij}. \] (4)

where \( LbsRelease \) is defined as the total pounds caught that must subsequently be released. The specification in equation (4) is employed throughout our estimation in order to achieve a large reduction in the number of estimated parameters.

Note that in equation (4), \( Price \) is specific to a respondent. The full price is composed of fishing cost \( (FC) \), travel cost \( (TC) \), lodging cost \( (LC) \), and the opportunity cost of time \( (OC) \):

\[ Price_{nij} = FC_{ij} + TC_{nij} + LC_{nij} + OC_{nij}. \] (5)

Fishing cost is the only component of the \( Price \) that is an attribute in the experimental design; the other cost components are specific to an individual.\(^\text{15}\) Travel costs are calculated by multiplying exogenous per-mile operating costs by the respondent-specific round-trip distance to the site.\(^\text{16}\) Lodging costs, taken as the median of reported lodging costs per night, are included for all respondents who reported lodging cost from the most recent trip. In order to calculate opportunity costs of time, the surveys collected data on the hourly wage rate and the use of paid and unpaid time off for fishing trips. This information allows us to compare the fit we obtain when using the standard 30% of wage rates to alternative specifications tied more directly to foregone wages. We find that using an opportunity cost of time equal to 30% of the wage rate for the respondents who take un-

\(^\text{14}\) Adding separate squared terms by size was simply untenable given the size of the existing model. In addition, this approach would still not allow for any cross-effects within a species across different sizes, which we felt was a desirable property. The exception to this rule is salmon. In order to incorporate cross-effects within the group of salmonids, combined salmon catch squared was included in the model, rather than separate squared terms for king catch and silver catch.

\(^\text{15}\) Fishing costs were defined as either private or charter boat costs, as seen in figure 3. Respondents then selected whether each listed trip (dependent on the type of fishing and whether or not they had access to a private boat) would be a private boat trip or charter boat trip. We assign either the private or charter cost based on these answers.

\(^\text{16}\) These data are collected in the survey prior to the DCE questions. Specifically, we ask respondents to provide the saltwater fishing site they most often use, conditional on targeting salmon or bottomfish. This level of detail allows us to measure the mileage component of travel cost. The program PC Miler (version 18.1) was used to calculate the round-trip distance to the listed fishing site for each respondent. If a respondent has never fished for saltwater salmon or bottomfish in the state, the closest site to the respondent’s residence is used. The per-mile costs were taken as the driving costs (operating costs, gas, maintenance, and tires) listed by AAA for a representative vehicle type (AAA 2006): $0.17. If a respondent travelled on an airline on the last fishing trip, the median airline cost was used in place of the automobile costs described above. Finally, some respondents stated they would use a rented vehicle for the trip; therefore, we add the median vehicle rental cost in such cases. Travel costs were equivalently defined for the opt-out for all cases in which the opt-out is defined as an in-state saltwater fishing trip by a respondent: \( Opt_{\text{inside}} \) and \( Opt_{\text{ocean}} \).
paid time off for fishing and no opportunity cost for the remaining respondents fits better than using 30% of the wage rate for all respondents.\footnote{17}

The time frame used to model all of the DCE trips is a day of fishing. This is primarily due to the fact that the attributes listed in the DCE tables correspond to daily costs and catch levels. A majority of respondents typically make single-day trips for the primary purpose of saltwater fishing. Respondents who would fish for multiple days on a single trip or who would use the trip for multiple purposes require a more in-depth calculation of cost: costs for multi-day trips are calculated as the average cost associated with a fishing day on a trip,\footnote{18} and non-fishing costs on multi-purpose trips are allocated using the proportion of fishing days to total days on the last trip, following Yeh, Haab, and Sohngen (2006).

**Estimation of Utility Parameters**

Estimation of equation (4) proceeds through the use of standard maximum likelihood methods for multinomial logit models if the \( \varepsilon \) above are assumed to consist of iid type I extreme value random variables. Since our DCE scenarios elicit a complete ranking of choices, we use the rank-ordered (or exploded) variant, first introduced by Beggs, Cardell, and Hausman (1981).

However, it is likely that systematic taste differences between anglers will cause \( \varepsilon \) to be correlated across choice situations and this necessitates an extension of the standard rank-ordered logit model to explicitly account for preference heterogeneity. The most likely place to observe such differences would be in the set of indicators describing the opt-out, \( \text{Opt}_t \), and trip types, \( \text{Type}_k \).\footnote{19} We account for these taste differences using two methods.

First, we allow respondents who own or have access to a private boat to have different estimated preferences for the opt-out and trip types than respondents who do not. Letting \( \text{Ownboat} \) be an indicator depicting a respondent who owns or has access to a private boat for a given option, we add the cross products of \( \text{Ownboat} \) and the full set of trip types, as well as the cross products of \( \text{Ownboat} \) and the subset of the opt-outs that relate most closely to saltwater boat ownership: \( \text{Opt\_inside} \) and \( \text{Opt\_ocean} \).

The second way in which we model taste differences is through the use of a mixed logit model. This allows us to control for respondent-specific contextual differences in the opt-out and trip types which can be confounded with attributes in our blocked experimental design. Economic theory provides little insight with respect to the proper distribution, so we follow a common assumption in the literature of specifying a normal distribution for all random parameters (Train 2003).

If we let \( \bar{A} \) denote the vector of random parameters (the sets of \( \alpha \) and \( \theta \)), \( \bar{A} \) denote the vector of nonrandom parameters (\( \delta, \beta, \rho, \rho_\alpha \), and \( \gamma \)), \( J_n \) denote the number of choice questions completed by a respondent, and \( P(Y_n|\bar{A}) \) denote the probability of observing a particular set of ranked alternatives for a respondent that are indexed in order, then it can be shown that:

\[
P(Y_n|\bar{A}_n, \bar{A}) = \int_{\bar{A}_n} \left( \prod_{j=1}^{J_n} \left( \prod_{i=1}^{2} \left( \frac{e^{\left( V_{nj}\left( C_\alpha \right) / \sigma \right)}}{\sum_{k=1}^{3} e^{\left( V_{nk}\left( C_\alpha \right) / \sigma \right)}} \right) \right) \right) f(\bar{A}_n|\mu, \Sigma) \, d\bar{A}_n, \tag{6}
\]
where \( \mu \) is the mean vector and \( \Sigma \) is the covariance of the multivariate normal mixing distribution \( f(\bullet) \). We restrict the off-diagonal elements of \( \Sigma \) to be zero and normalize the scale parameter (\( \sigma = 1 \)) for estimation. As the surveys employed stratified random sampling, the contribution of each observation was scaled to account for the implied stratification weights in the sample likelihood function.

No closed-form solution exists for equation (6), so we must use simulation to approximate this integral. We use 1,000 Halton draws to maximize the simulated log likelihood using Nlogit (version 4.0).

\[ \text{Estimation Results} \]

First, it should be noted that saltwater recreational fishing is an activity that is perhaps too complex to model succinctly while at the same time providing fishery managers with the level of detail necessary to quantify the relative economic efficiency of competing policies. Our effort to capture the attributes that describe a day of fishing requires an experimental design larger than any other we have encountered in the related literature. As seen in table 2, our experimental design allows a very large number of parameters to be efficiently estimated, indicating that this level of complexity can be handled by current experimental design methods.

Statistically significant parameter estimates for the trip type indicators support the notion that there is an important component of a fishing trip not fully described by catch, bag limits, or price. For each trip type, the effect is calculated as the sum of a random parameter (with associated mean and standard deviation) and, for respondents who own or have access to a private boat, a non-random parameter denoted by \( \text{Ownboat} \). The combination of these effects yields a set of two normally distributed random variables, allowing for a bimodal random distribution across the population which is shown to be supported empirically.

The effects of the opt-out indicators are calculated in the same fashion for the two most closely related to boat ownership: \( \text{Opt\_inside} \) and \( \text{Opt\_ocean} \). Other opt-out indicators are estimated as simple random parameters with single modes. Parameter estimates for this set of indicators clearly demonstrate the fact that respondents do not define the opt-out variables uniformly, as there is significant variation both across respondents and across opt-out indicators for a given respondent. This is intuitive, as we expect the opt-out variables to be defined on an individual level. This causes errors to be correlated across choices made by an individual in which the opt-out is equivalently defined.

Next we turn to the large number of parameters describing fishing attributes. Apart from a single (statistically insignificant) exception, anglers prefer catching larger fish to smaller fish for all species, and utility is decreasing in the number of pounds that must be released. This comes as no surprise. The relationship between the three sizes of catch for each species facilitates the depiction of the marginal effect of size, which has not been a focus of existing research. We find that an increase in size provides a less than proportional increase in utility, using the pounds per fish from the experimental design. This means that the total weight of fish caught is an incomplete measurement of preferences for fish catch. The utility associated with catching a given number of pounds of fish depends, in part, on the number of fish caught. This dependency is intuitive, as there is a catch component of fishing that is not captured by a simple aggregation over the number of pounds caught.
Table 2
Estimates of Utility Parameters

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient (Mean)</th>
<th>Coefficient (S.D.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Price ($\delta$)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OR bottomfish</td>
<td>−1.26815***</td>
<td>1.42671***</td>
</tr>
<tr>
<td>Ownboat</td>
<td>1.14512***</td>
<td></td>
</tr>
<tr>
<td>OR salmon</td>
<td>0.236951</td>
<td>1.62663***</td>
</tr>
<tr>
<td>Ownboat</td>
<td>1.27004***</td>
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</tr>
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<td>WA Ocean bottomfish</td>
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<td>1.44381***</td>
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<tr>
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<td>1.09034***</td>
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</tr>
<tr>
<td>WA Ocean salmon</td>
<td>−0.11434</td>
<td>1.46412***</td>
</tr>
<tr>
<td>Ownboat</td>
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<td>WA Inside bottomfish</td>
<td>−1.48376***</td>
<td>1.43922***</td>
</tr>
<tr>
<td>Ownboat</td>
<td>0.80337***</td>
<td></td>
</tr>
<tr>
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<td>1.49452***</td>
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<tr>
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<td><strong>Opt ($\alpha$)</strong></td>
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<td>1.72991</td>
</tr>
<tr>
<td>Ownboat</td>
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</tr>
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<td>Opt_freshwater</td>
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<td>2.29135***</td>
</tr>
<tr>
<td>Opt_otherstate</td>
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<td>1.63059***</td>
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<td><strong>Catch ($\beta$)</strong></td>
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<td></td>
</tr>
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<td>Halibut</td>
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<td></td>
</tr>
<tr>
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</tr>
<tr>
<td>Medium</td>
<td>1.50204***</td>
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<td>Large</td>
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<td>Rockfish</td>
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</tr>
<tr>
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<td>0.130522***</td>
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</tr>
<tr>
<td>Large</td>
<td>0.699937***</td>
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</tr>
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<td>Lingcod</td>
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<td>0.802498***</td>
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<tr>
<td>Medium</td>
<td>0.802498***</td>
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</tr>
</tbody>
</table>

Note: ***, **, * = significant at 1%, 5%, and 10%, respectively.
### Table 2 (continued)

**Estimates of Utility Parameters**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient (Mean)</th>
<th>Coefficient (S.D.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Catch</strong> ($b_n$)</td>
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<td></td>
</tr>
<tr>
<td>Hatchery silver</td>
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<td></td>
</tr>
<tr>
<td>Small</td>
<td>0.240327***</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>0.354157***</td>
<td></td>
</tr>
<tr>
<td>Large</td>
<td>0.442726***</td>
<td></td>
</tr>
<tr>
<td>Wild silver</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small</td>
<td>0.262385***</td>
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<tr>
<td>Medium</td>
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<tr>
<td>Large</td>
<td>0.408896***</td>
<td></td>
</tr>
<tr>
<td>Hatchery king</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small</td>
<td>0.542229***</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>0.788408***</td>
<td></td>
</tr>
<tr>
<td>Large</td>
<td>0.926633***</td>
<td></td>
</tr>
<tr>
<td>Wild king</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small</td>
<td>0.391009***</td>
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</tr>
<tr>
<td>Medium</td>
<td>0.557317***</td>
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</tr>
<tr>
<td>Large</td>
<td>0.693901***</td>
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<tr>
<td><strong>Catch</strong> ($\rho_n$)</td>
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</tr>
<tr>
<td>Halibut</td>
<td>-0.22859***</td>
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<tr>
<td>Rockfish</td>
<td>-0.00334***</td>
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<tr>
<td>Lingcod</td>
<td>-0.12734***</td>
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<tr>
<td>Salmon</td>
<td>-0.01222**</td>
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</tr>
<tr>
<td><strong>LbsRelease</strong> ($\gamma_n$)</td>
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</tr>
<tr>
<td>Halibut</td>
<td>-0.0178***</td>
<td></td>
</tr>
<tr>
<td>Rockfish</td>
<td>-0.00674</td>
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</tr>
<tr>
<td>Lingcod</td>
<td>-0.01362***</td>
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</tr>
<tr>
<td>Hatchery silver</td>
<td>-0.02461***</td>
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</tr>
<tr>
<td>Wild silver</td>
<td>-0.01726***</td>
<td></td>
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<tr>
<td>Hatchery king</td>
<td>-0.03249***</td>
<td></td>
</tr>
<tr>
<td>Wild king</td>
<td>-0.00961***</td>
<td></td>
</tr>
</tbody>
</table>

Respondents ($N$) 1,889  
Sample Size ($\sum n_j$) 6,906  
Log-likelihood -10,060.51

Note: ***, **, * = significant at 1%, 5%, and 10%, respectively.
Wild and Hatchery Salmon Results

Since the major focus of this article is a depiction of preferences for wild and hatchery salmon, we turn our attention to the estimated set of parameters for salmon in what follows.

First, we focus on the estimates for salmon catch ($\tilde{b}_m$). Due to the quadratic functional form of catch in our model (4), estimates of catch parameters should be considered jointly with catch-squared parameters ($\tilde{b}_m^2$). As previously noted, we felt that a single combined quadratic parameter for salmon catch was superior to separate quadratic terms for species, as this incorporates both within and across-species effects with a single parameter. The desirable characteristic of diminishing marginal utility implied by the quadratic functional form is coupled with the (typically) undesirable characteristic that marginal utility will be negative in some range. An examination of the range over which our estimates imply a negative marginal utility indicates that this is not a practical concern in our model, as marginal utilities remain positive through almost 10 fish for all species and sizes of salmon catch.

The estimated parameters for $LhsRelease (\tilde{v}_s)$ show the relative effects of binding regulations. While all negative and statistically significant, the relative magnitudes of these parameters indicate that a binding regulation has the greatest effect on the utility associated with hatchery king salmon, followed by hatchery silver salmon, wild silver salmon, and finally wild king salmon. The utility associated with wild salmon appears to be less affected by binding regulations. This will be an important driver of results provided later in the article.

Table 3 provides the estimated marginal WTP for wild and hatchery salmon by species and size. First, we note that these marginal WTP values provide a much-needed update to recreational use values, as existing studies of this region are outdated (e.g., Cameron and James 1985, 1987; Morey, Shaw, and Rowe 1991; Rowe et al. 1985). The values in table 3 also provide a tremendous increase in the level of detail. Existing studies of the region calculate WTP for catch ratios only (Layton, Brown, and Plummer 1999; Morey, Shaw, and Rowe 1991; Rowe et al. 1985) or at most include the weight of the largest fish (Cameron and James 1985, 1987), whereas we provide WTP that varies by species, size, wild or hatchery origin, and whether the fish can be legally retained.

Welfare calculations follow Small and Rosen (1981) and Hanemann (1999). Estimated marginal WTP values for each area, species, and size combination in table 3 are calculated as:

$$WTP = \left( \frac{\ln[\sum_i e^{(\psi_i^0(c))}] - \ln[\sum_i e^{(\psi_i^1(c))}]}{\delta} \right),$$

where the superscripts 0 and 1 denote baseline and changed levels of catch, respectively, and the alternatives, indexed by $i$, include a salmon fishing option and a non-fishing option.\textsuperscript{20} For all calculations in table 3, we hold $Catch_s = 1$ under the changed levels but note that the functional form implies a diminishing marginal $WTP_s$ as $Catch_s$ increases. Significance levels in table 3, and elsewhere throughout the document for nonlinear functions, are calculated using the procedure of Krinsky and Robb (1986).

There is a significant amount of variation exhibited across species and sizes of salmon (table 3). The range of marginal WTP values is over $190: from a low of $–10 for a 30-pound hatchery king salmon, which must be released, to a high of $180 for a 30-pound hatchery king salmon, which may be kept. A surprising result here is that the two most divergent WTP values are for the same species and size of fish; the only difference being whether or not the fish can be legally kept.

\textsuperscript{20} These calculations hold the boat ownership indicator variables, fishing costs, travel costs, and lodging costs, at the sample averages for each area. Random parameters are held at the means of the estimated distributions.
Table 3
Marginal WTP for Silver and King Salmon by Origin, Size, and Area

<table>
<thead>
<tr>
<th></th>
<th>Washington Ocean</th>
<th>Washington Inside</th>
<th>Oregon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hatchery silver catch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small</td>
<td>32.07***</td>
<td>39.68***</td>
<td>40.45***</td>
</tr>
<tr>
<td>Medium</td>
<td>49.46***</td>
<td>60.73***</td>
<td>61.85***</td>
</tr>
<tr>
<td>Large</td>
<td>63.66***</td>
<td>77.68***</td>
<td>79.09***</td>
</tr>
<tr>
<td>Hatchery silver release</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small</td>
<td>14.23**</td>
<td>17.78**</td>
<td>18.15**</td>
</tr>
<tr>
<td>Medium</td>
<td>12.97**</td>
<td>16.21**</td>
<td>16.54**</td>
</tr>
<tr>
<td>Large</td>
<td>8.25</td>
<td>10.32</td>
<td>10.57</td>
</tr>
<tr>
<td>Wild silver catch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small</td>
<td>35.45***</td>
<td>43.8***</td>
<td>44.64***</td>
</tr>
<tr>
<td>Medium</td>
<td>50.88***</td>
<td>62.44***</td>
<td>63.61***</td>
</tr>
<tr>
<td>Large</td>
<td>58.36***</td>
<td>71.41***</td>
<td>72.71***</td>
</tr>
<tr>
<td>Wild silver release</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small</td>
<td>22.67***</td>
<td>28.17***</td>
<td>28.73***</td>
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<tr>
<td>Medium</td>
<td>24.66***</td>
<td>30.62***</td>
<td>31.22***</td>
</tr>
<tr>
<td>Large</td>
<td>18.98***</td>
<td>23.62***</td>
<td>24.09***</td>
</tr>
<tr>
<td>Hatchery king catch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small</td>
<td>80.07***</td>
<td>97.14***</td>
<td>98.82***</td>
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<tr>
<td>Medium</td>
<td>123.61***</td>
<td>147.71***</td>
<td>150.07***</td>
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<tr>
<td>Large</td>
<td>149.62***</td>
<td>177.34***</td>
<td>180.02***</td>
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<td>Hatchery king release</td>
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<td></td>
</tr>
<tr>
<td>Small</td>
<td>28.63***</td>
<td>35.48***</td>
<td>36.16***</td>
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<tr>
<td>Medium</td>
<td>17.29***</td>
<td>21.56***</td>
<td>22.01***</td>
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<tr>
<td>Large</td>
<td>−8.07</td>
<td>−10.1</td>
<td>−10.32</td>
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<tr>
<td>Wild king catch</td>
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<tr>
<td>Small</td>
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<td>67.81***</td>
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<tr>
<td>Medium</td>
<td>82.6</td>
<td>100.11***</td>
<td>101.83***</td>
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<tr>
<td>Large</td>
<td>106.37***</td>
<td>127.83***</td>
<td>129.91***</td>
</tr>
<tr>
<td>Wild king release</td>
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<tr>
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<td>50.73***</td>
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<tr>
<td>Medium</td>
<td>51.19***</td>
<td>62.8***</td>
<td>63.97***</td>
</tr>
<tr>
<td>Large</td>
<td>57.65***</td>
<td>70.53***</td>
<td>71.82***</td>
</tr>
</tbody>
</table>

Note: ***, **, * = significant at 1%, 5%, and 10%, respectively, using the method of Krinsky and Robb (1986).

We illustrate some of the characteristics of WTP estimated by our model, using wild king salmon as the example (figure 4). WTP for all three sizes of wild king salmon is estimated under the assumption that the catch of other salmon is zero and the bag limit is equal to one. WTP values are averaged across the three areas from the survey in the figure. The effect of binding regulations can be seen by comparing the slope of WTP above and below the limit; this simply implies that marginal WTP is lower for fish that have to be legally released. The estimated functional form (4) implies that there is no effect on utility of a change in a slack constraint,21 \( (\partial U/\partial \text{bag limit})_{\text{bag limit}=\text{catch}} = 0 \), and this can be seen in figure 4.

Here we begin to see that wild and hatchery salmon are not perfect substitutes to the recreational angler, as patterns of significant differences emerge. In order to make this more transparent, we exploit the full level of detail provided by our estimated model.

21 This is a common feature of the theoretical models in the literature that examine the effect of bag limits (e.g., Anderson 1993, Scrogin et al. 2004, Woodward and Griffin 2003).
and test differences across all areas, sizes, and species in the experimental design (table 4). This leads to six separate tests for each species in each area: three sizes for catch that can be kept and three sizes for catch that must be released. These tests are calculated as the estimated WTP for a wild salmon minus the corresponding estimate for a hatchery salmon; significant positive (negative) values in table 4 represent a higher (lower) WTP for a wild salmon relative to its hatchery-reared counterpart.

### Table 4
WTP Differences between Wild and Hatchery Salmon

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Silver catch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small</td>
<td>3.38</td>
<td>4.12</td>
<td>4.19</td>
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<tr>
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<td>1.41</td>
<td>1.71</td>
<td>1.75</td>
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<td>Large</td>
<td>–5.3</td>
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<td>–6.38</td>
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<tr>
<td>Silver release</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Small</td>
<td>8.44**</td>
<td>10.39**</td>
<td>10.58**</td>
</tr>
<tr>
<td>Medium</td>
<td>11.69**</td>
<td>14.41**</td>
<td>14.68**</td>
</tr>
<tr>
<td>Large</td>
<td>10.73*</td>
<td>13.3*</td>
<td>13.52*</td>
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<td></td>
</tr>
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<td>Small</td>
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<td>–29.33***</td>
<td>–29.78***</td>
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<td>–47.6***</td>
<td>–48.23***</td>
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<tr>
<td>Large</td>
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<td>–49.51***</td>
<td>–50.1***</td>
</tr>
<tr>
<td>King release</td>
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</tr>
<tr>
<td>Small</td>
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<td>14.31***</td>
<td>14.57***</td>
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<tr>
<td>Medium</td>
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<td>41.96***</td>
</tr>
<tr>
<td>Large</td>
<td>65.72***</td>
<td>80.63***</td>
<td>82.14***</td>
</tr>
</tbody>
</table>

Note: ***, **, * = significant at 1%, 5%, and 10%, respectively, using the method of Krinsky and Robb (1986).
Recreational Value of Wild and Hatchery Salmon

Given the level of detail in the estimates, there are many ways in which the WTP for wild and hatchery salmon could diverge. We turn first to examine WTP for salmon that may be retained. There are no significant differences observed between the WTP estimates of equally sized wild and hatchery silver salmon. In contrast, all three sizes of king salmon catch that may be kept exhibit significant differences; WTP values for hatchery king salmon are $25 to $50 higher than those of equally sized wild king salmon. This result is congruent with focus groups and one-on-one interviews with anglers. Some anglers indicated that they release wild salmon they could legally keep due to a conservation motive. The surveys simply present fish that would be caught on a trip and the corresponding legal daily limit. The only preferences we can measure, therefore, are those for fish that can be kept versus those that must be released. An individual angler may choose to keep a hatchery salmon yet release a wild salmon even if both fish could have been legally retained. An apparent preference for hatchery salmon that can be kept relative to wild salmon that can be kept might not imply a similar preference ordering for salmon that are actually kept.

The most consistent differences observed in table 4 are related to fish that must be released. Across species and sizes, anglers would rather release wild salmon than hatchery salmon. The magnitude of these differences ranges from a modest $8 for small silvers to a more sizeable $82 for large kings. This set of preference orderings indicates that anglers see a very real difference between the required release of wild salmon and the required release of hatchery salmon. Releasing a wild salmon, especially in a population listed as threatened or endangered under the ESA, is perhaps easier for anglers to justify or even support; it is designed to help the survival of a species. Making the case for the release of hatchery fish is more difficult, since the intended end use of many hatchery salmon is to fulfill a quota deemed necessary for artificial propagation or provide opportunity for some other recreational or commercial fisher. Furthermore, after the quota has been met, the excess salmon are deemed no longer useful to the hatchery and are euthanized. Being asked to release a fish to aid the survival of a species is quite different than being asked to release a fish that might end up being euthanized at a later point in time.

Simulations of Catch and Bag Limits

In order to simulate changes in catch rates and bag limits for salmon, we integrate the angler preferences estimated above with an auxiliary set of creel data collected in the fishery. Our approach is to use the actual bag limits, catch, and size distributions for salmon, as well as species that serve as substitutes (e.g., bottomfish), to create a baseline that allows WTP to be conditioned on current fishery conditions.

Simulation Data and Approach

For expositional ease, we limit the presentation of simulation results to changes in the catch and bag limits for king salmon in Washington. The data we use to simulate the effect of changes in levels of catch and regulations come from sampling programs conducted by the Washington Department of Fish and Wildlife (WDFW). Creel interviews

22 While many of the surplus hatchery salmon are put to some form of beneficial use (e.g., given to food banks, used to increase stream nutrients), the only option in which fish are not euthanized is when hatchery fish are allowed to pass upstream to spawn naturally, but this is rarely employed as hatchery fish spawning instream could interfere with wild populations (e.g., Kostow 2009).

23 Anecdotal evidence from focus groups and one-on-one interviews seems to support this finding. Many anglers expect to be able to keep a majority of the hatchery fish they catch. These same anglers seem more sympathetic to the cause of protecting wild salmon, which may be furthered with lower bag limits.
Anderson and Lee conducted at the boat level between 2006 and 2008 form the basis of the simulation data: the distribution of catch. Port-level sampling allows us to retain the distinction between the Inside and Ocean Areas in Washington in these data. After standardizing, removing outliers, and arranging the creel interviews so that each row corresponds to a single fishing trip, we calculate the average catch per angler and expand each row by the number of anglers represented on each interview (the number of anglers on the boat).

The length of the fish caught is collected on a subsample of creel interviews or is collected in a similar sampling effort through WDFW observers placed on charter boats, test boats operated by WDFW, or voluntary trip reports submitted by salmon anglers. However, among the records with sampled lengths, only a subset also contains measured weights. In cases where length data were provided without corresponding weight data, existing length-weight pairs are used to estimate a series of models that we use to impute any missing weights by area and species. Where data allow, separate models are fit for each area-species combination. The resulting weight files are used to randomly assign a weight to each fish caught in the creel interview data. Due to limitations in the sampling programs, the sizes we are able to collect in many cases are limited to retained fish.

In order to facilitate the use of continuous weight variables in the econometric model, which handles weights in a more discrete manner, each randomly drawn weight is placed into the closest of three bins in order to correspond to one of the three sizes from the experimental design. The result is a file where each row contains the catch of three sizes of each species. This approach is used to account for the catch of fish with weights between or outside the weights used in the experimental design.

From the full set of completed creel interviews, we save a randomly drawn sample of 100,000 interviews in each state as the base files to use in simulations. Next, from these base files, we draw 50 random samples with different fish catch and sizes, with the number of rows equal to the number of completed surveys from each state. To each sample, we apply baseline catch and regulations to generate model attributes (catch by size and pounds released) and then simulate changes to generate model attributes at the new levels of catch and regulations. For each draw of catch, we draw 50 random sets of parameters from the estimated distributions of random parameters in the model in order to incorporate the estimated preference heterogeneity. For each combination of catch and random parameter draws, we draw 50 random sets of all model parameters from the asymptotic distribution of the parameter estimates. Therefore, our simulation procedure provides 125,000 draws of WTP for each respondent in our sample. Parameter draws enable us to generate confidence intervals for WTP (Krinsky and Robb 1986).

For each respondent, WTP is evaluated over the empirical distribution of catch, the estimated distribution of random parameters, and the asymptotic distribution of all parameter estimates:

\[
WTP_n = \int \ldots \int \left( \ln \left( \sum_i e^{(\psi_i(\Lambda_n,c_n))} \right) - \ln \left( \sum_i e^{(\psi_i(\Lambda_n,c_n))} \right) \right) f(\Lambda, \tilde{\Lambda}_n, c_n) \, d\Lambda \, d\tilde{\Lambda}_n \, dc_n, \tag{8}
\]

where \(c_n\) denotes the full vector of catch by species and size, \(\Lambda\) denotes the vector of parameter estimates, and \(\tilde{\Lambda}_n\) denotes the vector of random parameters. While similar to the

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24 We define outliers as the top 1% of catch per angler in order to remove a handful of trip interviews with unbelievably high levels of reported catch.

25 Data from on-board observers are the source of length measurements for both king and silver salmon in the Ocean area of Washington. Test boat data include length measurements for king salmon in the Inside area of Washington. Angler-reported length data for silver salmon as well as king salmon in the Inside area of Washington are taken from voluntary trip reports submitted by salmon anglers. All remaining length data are taken from creel interviews.
standard approach of applying the average levels of catch, evaluating WTP over the distribution of catch allows us to incorporate binding limits where they occur. The superscripts 0 and 1 again refer to baseline and changed levels of catch and bag limits, respectively, but now baseline levels are set equal to observed catch and bag limits observed in the fishery. The alternatives, indexed by \( i \), include a salmon alternative in the Ocean area, a bottomfish alternative in the Ocean area, a salmon alternative in the Inside area, a bottomfish alternative in the Inside area, and a non-fishing alternative. We present results from this approach after averaging over the draws of parameters and catch, yielding mean WTP per respondent:

\[
\overline{WTP}_n = \frac{1}{50} \sum_{\lambda} \left( \frac{1}{50} \sum_{\tilde{\lambda}_n} \left( \frac{\ln \left[ \sum_{\lambda} \left( \frac{p_{1}^{0} (\lambda, \tilde{\lambda}_n, \epsilon_n)}{\delta} \right) \right]}{- \ln \left[ \sum_{\lambda} \left( \frac{p_{1}^{1} (\lambda, \tilde{\lambda}_n, \epsilon_n)}{\delta} \right) \right]} \right) \right), \tag{9}
\]

and use the 5th and 95th percentiles of the distribution of \( \Lambda \) and \( \tilde{\lambda}_n \) to generate confidence intervals.

**Catch and Bag Limit Scenarios**

We simulate two changes in bag limits relative to baseline (2010) levels: a one-unit increase in the king salmon limit and a one-unit increase in the wild king salmon limit. We provide the full set of associated bag limits for reference in table 5. As an example, increasing the wild king limit by one unit is accomplished by dropping the baseline wild king limit, in which the wild king limit = 0. This would allow one wild king to be kept, as the overall king salmon limit = 1.

Two scenarios are used to illustrate the effect of a change in wild and hatchery catch levels. We choose a 25% increase for hatchery king catch and, for the second scenario, solve for the percentage increase in wild king catch that equates, in levels, the increase in hatchery catch to the increase in wild catch. This is accomplished by setting the wild king catch increase to 12.6%. For reference, table 6 provides the percentage increase in catch of wild and hatchery salmon for both scenarios, relative to the creel survey baseline.

**Table 5**

<table>
<thead>
<tr>
<th>Bag Limits for King Limit Change and Wild King Limit Change Scenarios</th>
</tr>
</thead>
<tbody>
<tr>
<td>King Limit Change</td>
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<tr>
<td>-------------------</td>
</tr>
<tr>
<td>Baseline</td>
</tr>
<tr>
<td>Total salmon limit</td>
</tr>
<tr>
<td>King limit</td>
</tr>
<tr>
<td>Silver limit</td>
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<tr>
<td>Wild king limit</td>
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<tr>
<td>Wild silver limit</td>
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Note: 'n/a' should be interpreted as no additional limit.
Simulation Results

We present the results of the bag limit and catch simulations in figures 5 and 6, respectively. Cumulative density functions (CDF) of mean WTP are provided alongside the 5th and 95th percentiles. Figure 5 compares the WTP for one-unit increases in the wild king limit and overall king limit. A somewhat surprising result here is that anglers place a higher value on a change in the wild king limit ($1.45) than a change in the overall king limit ($0.26). This seems to be in contrast from the findings in table 4. However, this is simply a result of increasing limits that are not equally binding; the baseline level of wild king limit is more often binding than the baseline level of the overall king limit. This illustrates the importance of conducting policy simulations using the actual conditions in the fishery; the standard set of marginal values lead a reader to infer that an increase in the overall king limit would have a greater effect than a corresponding increase in the wild king limit, when the opposite is true.

Figure 6 compares the WTP for a 25% increase in hatchery king catch to a 12.6% (equivalent in levels) increase in wild king catch. Increases in hatchery catch are more highly valued than increases in wild catch at baseline catch and bag limits; most hatchery king catch could be kept, whereas wild king catch would have to be released. The average WTP is $1.83 for the increase in wild king salmon catch, compared with $2.48 for hatchery king salmon catch.

<table>
<thead>
<tr>
<th></th>
<th>Hatchery King Catch Increase</th>
<th>Wild King Catch Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wild king catch</td>
<td>0%</td>
<td>12.6%</td>
</tr>
<tr>
<td>Hatchery king catch</td>
<td>25%</td>
<td>0%</td>
</tr>
</tbody>
</table>

These CDFs are weighted in order to account for the stratified random sampling used.
Conclusions

Through the use of two recently administered choice experiments in Washington and Oregon, we measure WTP for hatchery and wild salmon separately across species, size, and whether or not the fish may be legally retained. Larger sizes of fish are preferred over smaller sizes, though this increase is less than proportional. We model catch that must legally be released as additively separable from catch that may be retained and see that, in most cases, the utility gain associated with catching a salmon is not entirely offset by the utility loss associated with having to release the same fish.

Observed differences in estimated marginal WTP indicate statistically significant differences in preferences for hatchery and wild salmon. WTP values for hatchery king salmon that can be kept are higher than the corresponding values for wild king salmon, perhaps indicating that some of the wild king salmon that could be retained would in fact be released. Across species and sizes, anglers would rather release wild salmon than hatchery salmon. This set of preference orderings indicates that anglers see a very real difference between the required release of wild salmon and the required release of hatchery salmon.

These marginal WTP values use a stylized baseline and may be better suited to illustrate general preferences than to answer specific policy questions. We therefore integrate the econometric model with creel survey data taken from state sampling programs in order to conduct policy simulations. We illustrate the approach with scenarios that vary the bag limit and catch levels for king salmon in Washington. At the baseline set of regulations, increases in hatchery king catch are more highly valued than increases in wild king catch. At the baseline set of catch levels, increases in the wild king limit are more highly valued than increases in the overall king salmon limit. Here we find that the conservation motive observed in table 4, whereby anglers are less impacted by regulations requiring the release of wild salmon relative to hatchery salmon, may be overpowered by the opposing effect of the current suite of bag limits that are more often binding for wild salmon. This apparent contradiction simply illustrates the importance of using the true baseline conditions in WTP calculations. Though it requires additional effort, we feel that researchers using a choice experiment to evaluate policy changes in a recreational fishery should use auxiliary creel data to construct a baseline in order to generate a more pertinent set of WTP values.

Figure 6. CDFs of WTP per Choice Occasion for Equivalent Increase in Catch
References


