Costs of Delaying Conservation: Regulations and the Recreational Values of Exploited and Co-occurring Species

Leif E. Anderson, S. Todd Lee, and Phillip S. Levin

ABSTRACT. *Several species of rockfishes (*Sebastes *spp.) in the Puget Sound of Washington have recently been listed under the Endangered Species Act. Bag limits for rockfishes have been restricted as a result, and recreational bycatch may prompt additional restrictions on trips targeting co-occurring species. A mixed logit model is estimated on discrete choice experiment data in order to simulate the effects of a set of regulations intended to conserve rockfish populations on recreational use values. Measures intended to limit rockfish bycatch mortality are shown to have economic impacts that are orders of magnitude larger than a direct adjustment in rockfish regulations.* (JEL Q26, Q51)

I. INTRODUCTION

The inadvertent capture and subsequent discard of nontarget species by commercial or recreational fishers is a critical issue for marine resource managers. Recent estimates suggest that 28% of captured fish and invertebrates are discarded in the United States, with values in excess of 50% for some fisheries (e.g., highly migratory species) or regions (e.g., southeastern United States) (Harrington, Myers, and Rosenberg 2005). The incidental bycatch of nontarget species can create changes in ecosystem structure and function through the removal of apex predators, and by increasing mortality rates of at-risk mammals, birds, turtles, and fishes that are long-lived and have low rates of reproduction (Hall, Alverson, and Metuzals 2000).

In this article we explore the interaction between regulations that contribute to the recovery of rockfishes (*Sebastes* spp.), harvest of co-occurring species targeted by recreational fishers, and recreational use values. In 1999, 14 species of rockfishes were petitioned for Endangered Species Act (ESA) listing in Puget Sound, USA. In 2010, one of these (bocaccio, *Sebastes paucispinis*) was listed as endangered and two (canary rockfish, *Sebastes pinniger,* and yelloweye rockfish, *Sebastes ruberrimus*) were listed as threatened (Endangered and Threatened Wildlife and Plants 2010).

With more than 60 species of rockfishes off the California, Oregon, and Washington coast, the genus *Sebastes* forms the core of the U.S. Pacific Coast groundfish fishery (Parker et al. 2000). Rockfishes are among the longest-lived fishes, with some maximum ages in excess of 150 years, and ages of maturity as late as 20 years (Love et al. 2002). These life history traits in concert with highly variable success in recruitment to juvenile stage (Love, Yoklavich, and Thorsteinson 2002) contribute to the very low intrinsic population growth of many rockfishes (e.g., Tolimieri and Levin 2005), rendering them particularly susceptible to overfishing[1] (Parker et al. 2000). A historical account of the exploitation of rockfishes by the commercial and recreational fisheries in Puget Sound makes this susceptibility ap-

[1] Murawski (2000) provides a set of criteria under which ecosystems can be considered overfished. Our use of the term *overfishing* is based on the following condition: biomasses of rockfish species have fallen below minimum biologically acceptable limits.

The authors are, respectively, economist, Fishery Resource Analysis and Monitoring Division; supervisory economist, Fishery Resource Analysis and Monitoring Division; and supervisory fisheries biologist, Conservation Biology Division, all at the Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Seattle, Washington.

Land Economics • May 2013 • 89 (2): 371–385
ISSN 0023-7639; E-ISSN 1543-8325
© 2013 by the Board of Regents of the University of Wisconsin System

parent in the context of this region (Williams, Levin, and Palsson 2010). The overall abundance of rockfishes has declined by approximately 70% over the last four decades in Puget Sound, and the rate of decline is believed to have been even more severe for species such as bocaccio, canary, and yelloweye (Drake et al. 2010). Recent research suggests that overfishing in both the commercial and recreational sectors was a significant factor in this decline in overall rockfish abundance (Williams, Levin, and Palsson 2010).

Beginning in the mid-1980s the management of rockfishes in Puget Sound by the Washington Department of Fish and Wildlife (WDFW) has been characterized by increasing restrictions on commercial and recreational fishing, culminating in a commercial fishing ban in 1994 (Williams, Levin, and Palsson 2010) and recreational ban in 2010 (WDFW 2010a). Rockfish bag limits have been steadily decreasing since the first bag limit of 15 was decreased in 1983 to 10 rockfishes in the northern portion and 5 rockfishes in the southern portion of Puget Sound (Palsson et al. 2009). In 1994, rockfish bag limits were further reduced to five in the north and three in the south. Additional changes occurred in 2000 when bag limits were reduced to one, with the added restriction in 2002 that no yelloweye or canary could be retained. In 2010, a no retention policy for any rockfishes was enacted for most of Puget Sound, with only a few areas remaining that allow rockfishes to be retained. Even though fishing mortality has been reduced, rockfishes have such low intrinsic productivity (Love, Yoklavich, and Thorsteinson 2002) that their populations have not rebounded (Drake et al. 2010). Thus, in retrospect, the initial management action has been considered to be insufficient (Williams, Levin, and Palsson 2010), as rockfish populations have exhibited continuing declines in abundance (Drake et al. 2010).

Even under a no rockfish retention policy, the amount of bycatch while targeting other species may lead fishery managers to impose further constraints on anglers. The ESA listing explicitly included recreational bycatch as a factor contributing to extinction risk (Endangered and Threatened Wildlife and Plants 2010). Not surprisingly, bycatch of rockfishes occurs while targeting most other species in Puget Sound, as successful targeting (or avoidance) of a distinct species in hook-and-line fisheries is quite difficult.[2] Recreational bycatch would be less critical if the survival rate of released rockfishes were high. However, pressure-related injuries (barotrauma) are commonly incurred during capture,[3] and the high mortality rate from barotrauma in rockfishes that are released increases the likelihood with which fishery managers will be forced to consider imposing restrictions on trips targeting co-occurring species such as lingcod *(Ophiodon elongatus),* Pacific halibut *(Hippoglossus stenolepis),* and Pacific salmon (*Oncorhynchus* spp.).

There are currently no estimates of the effect of these potential future restrictions on effort levels or recreational use values in the fishery. We estimate willingness to pay (WTP) measures for a set of fishery regulations that impose increasing restrictions designed to address rockfish catch and bycatch on angler trips in Puget Sound. We follow what is currently believed to be the most likely future path of fishery management[4] in determining the order in which these regulations are applied. Specifically, we examine WTP for four scenarios relative to baseline bag limits: (1) a

[2] However, some of the patterns in the bycatch data are not expected. In particular, the degree of rockfish bycatch observed on trips targeting salmon is quite high: anglers targeting salmon in Puget Sound landed approximately 25% of the total rockfishes caught between 2004 and 2007. This is surprisingly more than an order of magnitude higher than anglers targeting a key bottomfish species: Pacific halibut (Palsson et al. 2009). Although this is likely an artifact of the relative number of halibut and salmon trips in the area and not reflective of a similar difference in bycatch measured on a per trip basis between halibut and salmon trips, the overall level of rockfish bycatch on salmon trips seems sufficient to warrant a potential salmon closure scenario.

[3] For example, see Jarvis and Lowe (2008) and Parker et al. (2006).

[4] This construct relied on reading through the WDFW Environmental Impact Statement for the Puget Sound Rockfish Conservation Plan (WDFW 2010b), ESA listing document (Endangered and Threatened Wildlife and Plants 2010), a technical review document of Puget Sound rockfish populations conducted by WDFW (Palsson et al. 2009), and WDFW fishing regulations (WDFW 2011).

rockfish closure, (2) a rockfish and lingcod closure, (3) a rockfish, lingcod, and halibut closure, and (4) a rockfish, lingcod, halibut, and salmon closure. WTP is calculated using simulations of a mixed logit model estimated on discrete choice experiment (DCE) data recently conducted with a sample of marine anglers in Washington. A large set of creel survey data gathered separately from the DCE data provides a baseline for WTP calculations. These scenarios provide fishery managers with the information necessary to better understand the impact of policies designed to limit rockfish mortality in the recreational fishery on angler welfare, as well as the substitution between target species groups, Puget Sound and ocean area fishing, and other activities. Moreover, estimates of changes in participation can be used to estimate regional economic impacts.

In what follows, we discuss the DCE data and econometric modeling. Next, we turn to the methods and creel survey data used to conduct policy simulations.

II. DCE DATA

The data we use to model angler preferences are the product of a mail survey of anglers in the state of Washington. During 2006 and 2007, approximately 8,000 anglers were randomly selected from the population of adult anglers that held a license that allowed them to fish in saltwater. The survey instrument was tested at length and revised using input from focus group and one-on-one interviews conducted with anglers across the state.

Anglers were first contacted by telephone in order to screen out anglers who had not fished in saltwater within the last 12 months. The remaining contacts were devoted to confirmed saltwater anglers and anglers who could not be reached by telephone. Mail survey implementation generally followed the approach suggested by Dillman (2000). The full survey mailing included up to six total contacts: an initial telephone survey, a prenotice letter, the first full mailing of the survey, a postcard reminder, the second full mailing of the survey, and the third full mailing of the survey. The survey achieved an effective response rate of 48% among saltwater anglers in Washington.[5]

The survey included a section of DCE questions that provide the basis for estimating angler preferences. Each DCE question presented respondents with a set of three choices that varied the attributes that described a saltwater fishing trip. The attributes and levels selected for inclusion in the choice sets were generated through a process of experimental design.

Experimental Design

An experimental design[6] was used to create 50 different versions of the survey, one of which was randomly assigned to each respondent. Each version had three DCE questions, and each DCE question had three choices. The experimental design included attributes describing catch, fishing regulations, and fishing cost. The catch dimension of the design consisted of one size of pink salmon and three sizes of the seven other fish species[7] on the survey: Pacific halibut, lingcod, rockfish, hatchery coho, wild coho, hatchery Chinook, and wild Chinook. All attributes and levels were selected through survey pretesting.

DCE Questions

For illustrative purposes, Figure 1 provides an example DCE choice question. Each DCE question asked respondents to fully rank a set of three options: in this example, two bottom-fishing trips and an option to do something other than saltwater fish from a boat in the area (opt-out).

---

[5] For more information on the calculation of the effective response rate, see Anderson and Lee (2011).

[6] The procedure we used to generate the experimental design is discussed at length by Anderson and Lee (2011). In short, the final design was constructed using a search algorithm that attempts to maximize the D-efficiency of a representative choice model (Zwerina, Huber, and Kuhfeld 2005).

[7] Note that our use of *fish species* here does not map directly onto the proper definition of *species* for populations of Pacific salmon (Waples 1991). In addition, all rockfish species were combined in the survey instrument based on the results of focus group testing.

C2 Suppose that you have the choice between two boat fishing trips in the Inside area (Choice A or Choice B) or not taking a boat fishing trip in the Inside area (Choice C). Below the table, indicate which of these three choices you like best and second best.

		Choice A		Choice B		Choice C
Area	Boat boarding area	Inside area		Inside area		**Do one of the following** (other than boat fishing in the Inside area): • Ocean area fishing • Saltwater shore fishing • WA freshwater fishing • Non-WA fishing • Do some activity other than fishing
Halibut	Catch (weight per fish)	1 halibut (50 lb.)		2 halibut (15 lb.)		
	Legal daily limit	2 halibut		1 halibut		
Rockfish	Catch (weight per fish)	2 rockfish (4 lb.) 1 rockfish (6 lb.)		not targeted or caught on this trip		
	Legal daily limit	1 rockfish				
Cost	Fishing cost (per person per day) + Transportation cost + Lodging cost	**Private:** $40 + auto fuel / air + motel / camp	**Charter:** $125 + auto fuel / air + motel / camp	**Private:** $20 + auto fuel / air + motel / camp	**Charter:** $85 + auto fuel / air + motel / camp	

If you were presented these three choices (A, B, C), which one would you choose to do? **(mark only one)**

INSIDE Choice A ☐	INSIDE Choice B ☐	NO INSIDE Fishing Trip Choice C ☐

If your first choice was not available, what would be your second choice? **(mark only one)**

INSIDE Choice A ☐	INSIDE Choice B ☐	NO INSIDE Fishing Trip Choice C ☐

C2.1 For Choice A and Choice B, would you most often use a charter or private boat? **(mark one for each choice)**

Choice A		Choice B	
Private	Charter	Private	Charter
☐	☐	☐	☐

C2.2 If all of your INSIDE area boat fishing during the next 12 months had to be Choice A trips, Choice B trips, or a mix of Choice A and Choice B trips, how many TRIPS, if any, of each choice would you take during the next 12 months? How many total DAYS would you spend fishing for each choice? **(enter 0 if you wouldn't take any trips)**

Choice A		Choice B	
Trips next 12 months	Days next 12 months	Trips next 12 months	Days next 12 months
☐☐	☐☐	☐☐	☐☐

C2.3 Which one activity would you most likely do for Choice C? **(mark only one)**

☐ Ocean area fishing	☐ Saltwater shore fishing	☐ WA freshwater fishing	☐ Non-WA fishing	☐ Non-fishing activity

FIGURE 1
Example Choice Question

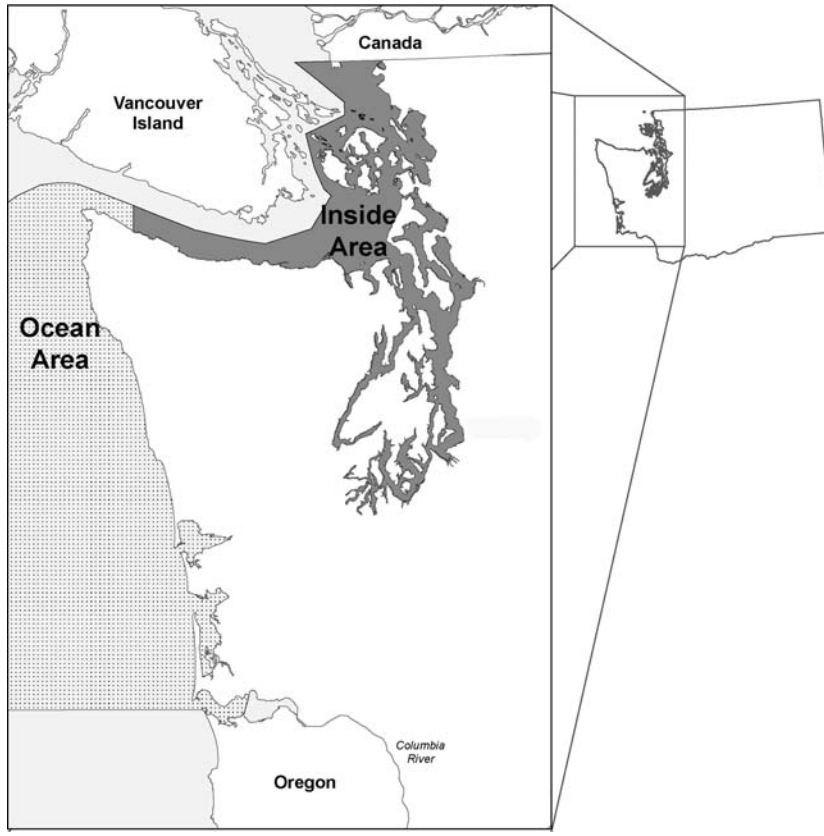

FIGURE 2
Inside Area and Ocean Area of Washington as Depicted in the Survey Instrument: Lighter (Darker) Gray Shading Is Ocean (Inside) Area, Equivalent to Marine Area 1 through Marine Area 4 (Marine Area 5 through Marine Area 13) in Washington Fishing Regulations

The DCE questions described each trip as either an Inside area or Ocean area trip. The Inside area roughly corresponds to Puget Sound (we use the two terms interchangeably in this article), but also includes the Strait of San Juan de Fuca and a portion of the Strait of Georgia (Figure 2). The terms Inside area and Ocean area were developed with the help of focus group participants. The survey instrument separated the state into the Inside area and Ocean area in order to ensure that the fishing location was consistently defined across respondents. When the survey was fielded, differences in fishing regulations between the two areas were quite large for some species: rockfish limits were almost an order of magnitude different between the two areas. While the Inside area is the focus of this article, the explicit inclusion of a very close substitute (trips in the Ocean area) serves to increase the validity of the resulting WTP estimates (e.g., Boxall et al. 1996). The full set of attributes and levels used in the DCE questions are provided in Table 1 for reference.

III. MODEL

McFadden (1974) provides the basis for modeling the DCE data. The utility that individual i receives from selecting alternative j on choice occasion t can be represented as

$$U_{ijt} = V_{ijt} + \epsilon_{ijt}, \quad [1]$$

TABLE 1
Experimental Design Attributes and Attribute Levels

		Inside Levels[a]	Ocean Levels[a]
Catch			
Halibut	15 lb	1,2	1,2
	25 lb	1,2	1,2
	50 lb	1,2	1,2
Rockfish	2 lb	1,2	8,10,12
	4 lb	1,2	8,10,12
	6 lb	1,2	8,10,12
Lingcod	5 lb	1,2,3	1,2,3
	10 lb	1,2,3	1,2,3
	15 lb	1,2,3	1,2,3
Hatchery silver salmon	5 lb	1,2,3	1,2,3
	10 lb	1,2,3	1,2,3
	15 lb	1,2,3	1,2,3
Wild silver salmon	5 lb	1,2,3	1,2,3
	10 lb	1,2,3	1,2,3
	15 lb	1,2,3	1,2,3
Hatchery king salmon	10 lb	1,2,3	1,2,3
	20 lb	1,2,3	1,2,3
	30 lb	1,2,3	1,2,3
Wild king salmon	10 lb	1,2,3	1,2,3
	20 lb	1,2,3	1,2,3
	30 lb	1,2,3	1,2,3
Pink salmon	3 lb	2,4	2,4
Bag limit			
Halibut		1,2	1,2
Lingcod		1,2,3	1,2,3
Rockfish		1,2	8,10,12
Wild silver salmon		0,1,2	0,1,2
Wild king salmon		0,1,2	0,1,2
Pink salmon		2,4	2,4
King salmon		1,2	1,2
Total salmon		2,4	2,4
Fishing Cost		20,40,80[b]	20,40,80[b]

[a] All attributes listed also include a missing level except cost.
[b] Private boat cost levels are shown. Charter boat levels are 85,125,175.

where V is deterministic and ϵ is stochastic and unobserved from the point of view of the researcher. If ϵ consists of iid type I extreme value random variables, the full rankings of DCE questions are exploited, and preferences are assumed to be homogeneous, then the rank-ordered logit model first proposed by Beggs, Cardell, and Hausman (1981) provides the framework for specifying the likelihood function. We let $P(Y_n \mid \beta)$ denote the probability of a particular set of alternatives, indexed in order. If T_i is the number of DCE choice questions completed by a respondent, then it can be shown that

$$P(Y_i \mid \boldsymbol{\beta}) = \prod_{t=1}^{T_i}\left(\prod_{j=1}^{2}\left(\frac{\exp\left(\frac{V_{ijt}(\cdot)}{\sigma}\right)}{\sum_{k=i}^{3}\exp\left(\frac{V_{ijt}(\cdot)}{\sigma}\right)}\right)\right), \qquad [2]$$

where σ is the scale parameter and $\boldsymbol{\beta}$ is the vector of parameters in V. Given the panel structure of the data and the possibility of taste differences between anglers, the ϵ values are likely to be correlated across choice occasions for a given respondent. Extending the model to explicitly account for preference parameter heterogeneity yields

$$P(Y_i \mid b, \tilde{\beta}_i) = \int_{\tilde{\beta}_i}\left(\prod_{t=1}^{T_i}\left(\prod_{j=1}^{2}\left(\frac{\exp\left(\frac{V_{ijt}(\cdot)}{\sigma}\right)}{\sum_{k=i}^{3}\exp\left(\frac{V_{ijt}(\cdot)}{\sigma}\right)}\right)\right)\right) f(\tilde{\beta}_i \mid \mu, \Sigma)\, d\tilde{\beta}_i, \qquad [3]$$

where $\tilde{\beta}$ and b denote the components of the parameter vector $\boldsymbol{\beta}$ that are treated as random and fixed, respectively. The mean vector and covariance matrix of the multivariate mixing distribution $f(\cdot)$ are given by $\boldsymbol{\mu}$ and $\boldsymbol{\Sigma}$, respectively. We model $f(\cdot)$ as multivariate normal for the purpose of estimation.

V is assumed to be a function of the full cost of a fishing trip (P), a set of indicator variables depicting the opt-out (Opt), fish catch (C), fish catch that exceeds the daily bag limit (R), and a set of indicator variables that describe general types of fishing trips ($Type$):

$$V_{ijt} = V(P_{ijt}, Opt_{rijt}, C_{jt}, R_{jt}, Type_{mjt}), \qquad [4]$$

where r is the index for the opt-out indicator variables and m is the index for trip type. A simple expansion of the catch and release variables by the species and sizes allowed for in the experimental design yields a very large model. Motivated by a desire to retain a slightly more tractable model, we aggregate the fish release by weight (pounds). The resulting specification is given by

$$U_{ijt} = \delta P_{ijt} + \sum_r \alpha_r Opt_{rijt} + \sum_s \sum_l \beta_{ls} C_{lsjt} + \sum_s \gamma_s LbsR_{sjt} + \sum_m \theta_m Type_{mjt} + \epsilon_{ijt}, \quad [5]$$

where s indexes species, l indexes sizes (in pounds), and *LbsR* is defined as the total number of pounds caught that must be released due to a binding bag limit. Calculating *LbsR* requires the assumption that larger fish are preferred to smaller fish within a given species.

Given the specification in [5], the effect of catching a single fish that can be kept[8] is β_{ls}. If the bag limit for species s is binding and the fish must be released, the effect instead becomes $\beta_{ls} + l\gamma_{ls}$.

Note that *Opt* in [5] is indexed by respondent, since the opt-out is likely to be defined at an individual level. As seen in Figure 1, the survey asked respondents to indicate whether the opt-out would be a saltwater shore fishing trip, a freshwater fishing trip, a fishing trip in another state, some nonfishing alternative, an Inside area fishing trip, or an Ocean area fishing trip.

The two areas (Ocean area and Inside area) and two major species groupings (bottomfish and salmon) from the survey form the basis for trip type indicator variables: *Type.* Specifically, we include the cross product of area by species: Ocean bottomfish, Ocean salmon, Inside bottomfish, Inside salmon. *Type* variables are included in the model in order to control for noncatch components of a fishing day that vary by area and species grouping, as survey pretesting uncovered significant preference heterogeneity across these dimensions.

Though not explicit in [5], the *Opt* and *Type* variables are also allowed to vary in systematic fashion with an angler's access to a boat that can be used for saltwater fishing. This is accomplished by adding the cross products of *Ownboat* (a variable indicating boat access or ownership) and *Type*, as well as the cross products of *Ownboat* and the two opt-out activities most closely related to saltwater boat access: Inside area and Ocean area boat fishing.

The full price in the model is composed of fishing cost, travel cost, lodging cost, and the opportunity cost of time. Fishing cost is an attribute in the experimental design. Other components of cost cannot be realistically separated from measures such as distance to the fishing site, which is inherently specific to an individual. In general, travel costs are generated as the product of American Automobile Association per-mile costs and round-trip distances to the fishing site.[9] Median nightly lodging costs are included for all respondents who report a lodging cost from the most recent fishing trip. Opportunity costs of time are taken to be 30% of the wage for respondents who reported taking unpaid time off for fishing, and zero for the remaining respondents.[10]

All trips are modeled from the perspective of a single day.[11] Multiday trip costs are simply averaged in order to produce an average daily cost for respondents who indicated that a trip would span multiple days. Multipurpose trips are handled using the approach suggested by Yeh, Haab, and Sohngen (2006): nonfishing costs are allocated using the proportion of fishing days to total days (based on the most recent trip).[12]

[8] Survey data allow us to determine whether a fish *could* be kept legally by a particular respondent, rather than whether it *would* be kept.

[9] The distances to fishing sites were calculated from the responses to questions that asked respondents to provide the sites used most often to fish for species group X in area Y. We used PC Miler (version 18.1) to calculate distances to fishing sites. Driving costs (operating costs, gas, maintenance, and tires) listed by the American Automobile Association from the same year were used for the per-mile costs: $0.17. Median airline costs or vehicle rental costs were used in place of per-mile driving costs for respondents who reported using an airline or renting a vehicle on the most recent fishing trip.

[10] This approach fits slightly better than a standard approach of using 30% of the wage rate for all respondents and does not substantively affect any of our results. For example, between these two specifications of opportunity cost, all parameter estimates for the catch and pounds released variables changed less than 2%, and all but one changed less than 0.5%. The parameter estimate for price changed 3.4%. These results are available from the authors.

[11] This necessitates the use of a model that holds the marginal value of successive days on a trip constant.

[12] Separate models are estimated for respondents who take multiday trips and those who take multipurpose trips. Although estimated WTP using the pooled data are somewhat larger in magnitude, none of the differences are statis-

IV. ESTIMATION

The parameters in [3] are estimated by the method of simulated maximum likelihood using Nlogit (version 4.0) with 1,000 Halton draws.[13] We restrict off-diagonal elements of Σ to zero and normalize σ to one for estimation.[14]

Even though we estimate such a large number of parameters, almost all of them are statistically significant at the 1% level. The patterns observed in Table 2 conform to our basic a priori expectations: larger fish are preferred to smaller fish,[15] the type of trip is a significant determinant of choices, anglers with boat ownership or access are more likely to saltwater fish, and there is significant heterogeneity in preferences for trip types and the different opt-out indicators.

We simplify the treatment of pink salmon in the final estimated model, including only a set of indicators for an Inside or Ocean area trip catching pink salmon, after a more complete specification including catch and release seemed to add more noise than signal.[16]

V. SIMULATIONS

Simulations Data

Model simulations require a distribution of catch, a distribution of size, and bag limits under the baseline and changed conditions, for each species. The model contains three sizes of catch and the quantity (in pounds) of fish that exceed the daily bag limit and must be released, so size and bag limits are necessary inputs. The same is also true for the distribution, as opposed to a more aggregate measure, of catch. A (desirable) characteristic of the model in [5] is that bag limits have an effect only when binding,[17] and it is precisely this characteristic that leads the model simulations to require a distribution of catch over trips.

WDFW creel survey data from 2006 through 2009 are used to provide the number of fish caught by species and the number of fish released by species. Weight data come primarily from length data and length-to-weight relationships we estimate on the subsample of observations that contain both length and weight measurements for a fish. These size data come from a combination of voluntary trip reports submitted by salmon anglers, on-board observers placed on charter boats, test boat anglers employed by WDFW, and creel interviews. Expected catch was used to frame the DCE questions. Therefore, our use of the creel data is intended to reflect, to some degree, angler expectations of the distribution of catch.

Preparing the creel data for simulations involves randomly drawing 500,000 records of catch, at the level of individual angler,[18] by the sizes and species included in the experimental design of the DCE data. For additional information on the data used in the simulations, see Anderson and Lee (2011).

Regulatory Scenarios

We consider four total regulatory scenarios that could be used to protect rockfish species in the Puget Sound. As will become clear, the order in which regulations are imposed has a large impact on the marginal effect of a particular regulation. We follow what is currently believed to be the most likely future path of fishery management in determining the order of scenarios: (1) a rockfish closure "R," (2) a rockfish and lingcod closure "R+L," (3) a rockfish, lingcod, and halibut closure

tically significant. These results are available from the authors upon request.

[13] See Train (2003) for a comprehensive treatment of simulation methods for choice models.

[14] The contribution of each observation was scaled to account for the stratified random sampling employed in the DCE survey, as discussed by Anderson and Lee (2011).

[15] A close examination of Table 2 shows that there is one nonmonotonic pair of estimates that serves as a possible exception to this rule; the point estimate for medium lingcod is higher than that for large lingcod. However, this difference is not statistically significant.

[16] These results are available from the authors upon request.

[17] See Anderson (1993), Woodward and Griffin (2003), and Scrogin et al. (2004) for examples of theoretical models of recreational fishing that have this feature.

[18] Most creel data are collected at the boat level. As such, we use the average catch per angler on an interviewed boat, weighted by the number of anglers on the boat, in the simulations in order to build catch profiles at the individual level.

TABLE 2
Parameter Estimates

Variable		Coefficient (Mean)	Coefficient (SD)
$P(\delta)$		−0.00292***	
$Type(\theta_m)$			
Ocean bottomfish		−0.96125***	1.38441***
	Ownboat	1.00134***	
Ocean salmon		−0.20869	1.47294***
	Ownboat	1.0313***	
Inside bottomfish		−0.8527***	1.34904***
	Ownboat	0.71581***	
Inside salmon		−0.24519	1.56268***
	Ownboat	1.33283***	
Ocean pink salmon		−0.25276**	
Inside pink salmon		0.0718	
$Opt(\alpha_r)$			
Ocean		−1.94768***	2.08424***
	Ownboat	1.51678***	
Inside		−0.59005	1.6509***
	Ownboat	0.66992*	
Shore		−0.68244**	3.05682***
Freshwater		−0.451***	2.12767***
Other state		0.39727**	1.56251***
$C(\beta_{ls})$			
Halibut	15 lb.	0.58039***	
	25 lb.	0.96268***	
	50 lb.	0.98327***	
Rockfish	2 lb.	0.01704*	
	4 lb.	0.07127***	
	6 lb.	0.08823***	
Lingcod	5 lb.	0.20205***	
	10 lb.	0.30525***	
	15 lb.	0.28631***	
Hatchery silver salmon	5 lb.	0.18546***	
	10 lb.	0.3559***	
	15 lb.	0.54008***	
Wild silver salmon	5 lb.	0.261***	
	10 lb.	0.29544***	
	15 lb.	0.50491***	
Hatchery king salmon	10 lb.	0.46471***	
	20 lb.	0.75279***	
	30 lb.	0.84156***	
Wild king salmon	10 lb.	0.40789***	
	20 lb.	0.67352***	
	30 lb.	0.96219***	
$LbsR(\gamma_s)$			
Halibut		−0.02916***	
Rockfish		−0.00921	
Lingcod		−0.01154**	
Hatchery silver salmon		−0.03381***	
Wild silver salmon		−0.01667***	
Hatchery king salmon		−0.02862***	
Wild king salmon		−0.01863***	
Respondents (I)	1,309		
Sample size ($\Sigma_i T_i$)	4,752		
Log-likelihood at zero	−9,519.655		
Log-likelihood at convergence	−7,693.204		

* Significant at 10%; ** significant at 5%; *** significant at 1%.

TABLE 3
Inside Area Bag Limits under Baseline and Closure Scenarios

Closure Scenario	Rockfish Limit	Lingcod Limit	Halibut Limit	Salmon Limit
Baseline	1	1	1	2
Rockfish (R)	0	1	1	2
R+Lingcod (L)	0	0	1	2
R+L+Halibut (H)	0	0	0	2
R+L+H+Salmon (S)	0	0	0	0

"R+L+H," and (4) a rockfish, lingcod, halibut, and salmon closure "R+L+H+S." All scenarios are measured relative to a baseline in which lingcod, halibut, and salmon remain open with a bag limit equal to 2010 levels, and the rockfish bag limit is set equal to 2009 levels. This allows us to also illustrate the effect of the recent rockfish closure. A fishery closure can be represented in our model by using one or more of the following: setting that fishery's bag limit to zero; setting that fishery's catch to zero; or eliminating that fishery from the choice set. We model the R scenario by setting the rockfish bag limits to zero. Similarly, the R+L scenario is modeled by setting both the rockfish and lingcod bag limits to zero. We choose this approach for these two scenarios since fishing for other bottomfish species would still be allowed under the R and R+L scenarios. In contrast, we model the R+L+H and R+L+H+S scenarios by eliminating those fisheries as an option in the choice set. We choose this approach since none of the bottomfish species in the survey may be targeted under the former and no bottomfish species or salmon may be targeted under the latter. The associated Puget Sound bag limits for these scenarios and the baseline characteristics are provided in Table 3. For all scenarios, the Ocean area regulations are fixed at 2010 levels.

Welfare Measures

In this fishery, anglers do not hold a property right to a particular management regime. Since the regulatory scenarios we consider reduce the quantity of an environmental amenity (e.g., fish that can be retained) or eliminate an option from the choice set altogether (e.g., a bottomfish closure), we measure WTP to avoid a reduction in catch.[19]

Small and Rosen (1981) and Hanemann (1999) have shown in the case of fixed coefficients and no income effects, WTP can be calculated as

$$\widehat{WTP} = \left(\frac{ln\left[\sum_j e^{(\hat{V}_j^0(\cdot))}\right] - ln\left[\sum_j e^{(\hat{V}_j^1(\cdot))}\right]}{\hat{\delta}} \right), \qquad [7]$$

where the superscripts 0 and 1 denote baseline and restricted levels of C and $LbsR$ for a given regulatory scenario. Five alternatives, indexed by j, are included in these calculations: a bottomfish trip in the Inside area, a salmon trip in the Inside area, a bottomfish trip in the Ocean area, a salmon trip in the Ocean area, and a nonfishing alternative.[20]

Relative to [7], calculation of WTP in the context of this article is complicated by two factors. First, the use of a mixed logit requires WTP to be calculated over the estimated parameter distributions. In a similar fashion, policy simulations of the econometric model in [5] require use of a catch distribution

[19] However, the combined results from Randall and Stoll (1980) and Hanemann (1991) show that in the case of changes in environmental amenities used or consumed by individuals, WTP and willingness to accept compensation (WTA) are equivalent if the income elasticity of demand (η) is zero or if there is perfect substitution between the good being valued and all other goods considered in the economic system. In our case, the functional form for V implicitly assumes that $\eta = 0$, and therefore WTP = WTA.

[20] Note, however, that some of the above scenarios that we consider eliminate one or more of these options from the choice set. Specifically, the bottomfish option in the Inside area is removed under the R+L+H scenario, and both Inside area options are removed under the R+L+H+S scenario.

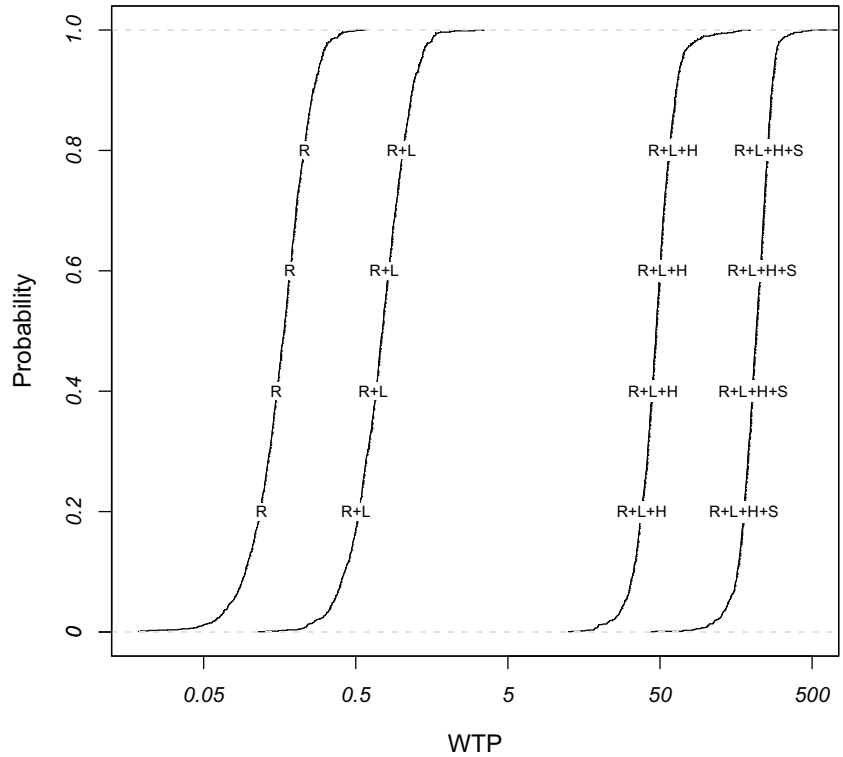

FIGURE 3
Cumulative Density Functions of Log-Scale Willingness to Pay (WTP) for Closure Scenarios

which, in turn, adds an additional dimension to the simulation of WTP. Under this framework, WTP per choice occasion for a respondent can be calculated as

$$\widehat{WTP} = \iiint_{b,\tilde{\beta}_i,C_i} \left(\frac{ln\left[\sum_j e^{(\hat{V}_j^0(\cdot))}\right] - ln\left[\sum_j e^{(\hat{V}_j^1(\cdot))}\right]}{\hat{\delta}} \right) f(b,\tilde{\beta}_i,C_i)dbd\tilde{\beta}_i dC_i, \quad [8]$$

which is approximated using simulation with 50 draws from each dimension of $f(b,\tilde{\beta}_i,C_i)$.[21]

[21] We use 50 draws, as opposed to a larger number, from each dimension of the joint distribution in [8] in order to make the simulations more manageable. Note that this process still yields a total of 156,375,000 draws (125,000 for each respondent in the sample). Sensitivity tests to different values of N show little variation in mean WTP with this many draws. These results are available from the authors upon request.

VI. RESULTS

The differences in preferences across anglers (Table 1) and the individual-level travel costs in the data imply a range of WTP over anglers. To capture this heterogeneity we describe WTP as a cumulative density function (CDF) over anglers (Figure 3).[22] A very large range of WTP values is observed across the scenarios, and as a result, a logarithmic scale is required to accommodate the CDFs.

As the closure scenarios we model monotonically impose restrictions on angler trips moving from the R scenario to the R+L+H+S scenario, the direction of the differences in WTP for closure scenarios is exactly

[22] The calculations underlying Figure 3 and elsewhere in the article are weighted appropriately to account for the oversampling of nonresident anglers in the DCE survey data, as described by Anderson and Lee (2011).

TABLE 4
Descriptive Statistics of Willingness to Pay by Scenario (dollars)

Closure Scenario	Mean	5th Percentile	Median	95th Percentile
Rockfish (R)	0.17	0.08	0.17	0.30
R+Lingcod (L)	0.78	0.36	0.75	1.34
R+L+ Halibut (H)	48.47	29.34	46.93	69.89
R+L+H+Salmon (S)	215.80	141.60	214.20	284.50

as anticipated: increasing restrictions result in higher WTP (Figure 3). However, the magnitudes of some of the differences are surprising. In particular, the relative difference between the R+L and R+L+H scenarios and the absolute difference between the R+L+H and R+L+H+S scenarios are quite large, with the latter being driven in part by a very high WTP for the full Inside area closure.[23] It appears that the welfare effect of a single bottomfish closure (e.g., rockfish) is highly moderated under scenarios in which anglers are still allowed to target another bottomfish in the same area. A full closure of either bottomfish or both bottomfish and salmon in Puget Sound imposes costs that are orders of magnitudes higher. Mean WTP varies from a low of $0.17 for the R scenario to $215.80 for the R+L+H+S scenario (Table 4).

In order to examine the statistical significance of the differences in WTP between closure scenarios, we use the method of random sampling, with replacement, from the full set of simulated differences between closure scenarios, as discussed by Poe, Giraud, and Loomis (2005). All differences are found to be statistically significant at the 1% level.[24]

It should be noted that the ordering of closures in this analysis greatly affects the marginal impact of each closure. For example, if Pacific halibut were closed prior to lingcod, then the marginal impact of the lingcod closure would be much greater than the WTP value we report here. This is due to the nonlinearity generated when entire options are eliminated from the choice set of saltwater anglers (e.g., Inside area bottomfish).

Whether the more complete closures will become necessary to conserve threatened or endangered species of rockfishes is not yet known, but the results presented here make it clear that the full welfare cost of rockfish conservation measures may in fact depend much more on the secondary measures designed to limit the bycatch of rockfishes than on a direct change in rockfish regulations. Moreover, delaying rockfish closures to the point where secondary closures are also necessary may impose higher costs in the long run.

Underlying the WTP calculations are changes in the probabilities of selecting each option. Participation rates under the four scenarios, relative to the baseline, show the degree to which anglers substitute out of Inside area fishing options to substitutes such as Ocean area fishing or other activities (Figure 4). An understanding of this substitution can help minimize the unintended consequences that closures may bring about on the fisheries that remain open. Closure scenarios with small values for estimated WTP cause correspondingly minor levels of substitution between options, seen by examining the (negligible) amount of substitution brought about by the R and R+L scenarios, relative to the baseline. The largest predicted shift in fishing effort occurs when Inside area salmon fishing is closed. Though this effort would be split across the three remaining options, the Ocean area salmon fishery would receive the greatest increase.

VII. CONCLUSION

This study considers the impact brought about by the historical absence or delay in reg-

[23] This is especially true given that substitutes such as Ocean area fishing are explicitly modeled in the choice experiment.

[24] Test results for the differences (R+L) – (R), (R+L+H) – (R+L), and (R+L+H+S) – (R+L+H) are $p = 0.006$, $p < 0.001$, and $p = 0.001$, respectively.

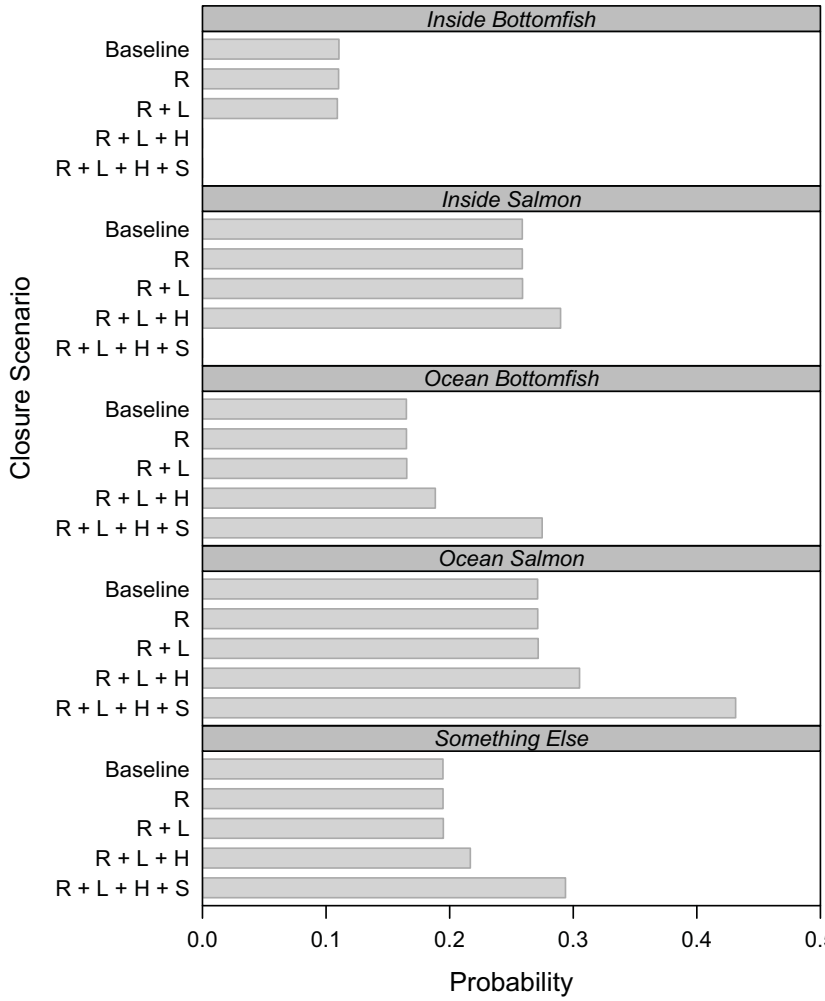

FIGURE 4
Mean Option Probabilities for Closure Scenarios

ulations intended to conserve Puget Sound rockfish species. We examine the WTP for a set of closure scenarios, applied incrementally, that could be used by fishery management in order to limit take of ESA-listed rockfish species by the recreational fishery. Simulations of a mixed logit model use a baseline constructed with creel survey data. The WTP values provided here should be of direct interest to fishery managers, as the closure scenarios included in this analysis have either been recently implemented or are likely to be considered in the future if the depressed populations of Puget Sound rockfishes do not rebound. Results show that the impact of closures involving an entire option in the choice set of saltwater anglers (e.g., Inside area bottomfish, full Inside area) vastly exceeds the impact of partial closures. While it may no longer, by itself, be sufficient to reverse the apparent population decline of some species (NMFS 2008), we find that a rockfish closure in Puget Sound is likely to have very little impact on anglers. In comparison, our simulations show that anglers' WTP for a full bottomfish closure or an entire closure of Puget

Sound is larger by multiple orders of magnitude. If either of these closures becomes necessary to conserve rockfish populations,[25] the historical delay in enacting relatively low cost rockfish conservation measures may be shown to have produced a future with much higher costs of achieving the same outcome.

Acknowledgments

This article and its findings do not necessarily reflect the views of the Department of Commerce, the National Oceanic and Atmospheric Administration, or the National Marine Fisheries Service.

References

Anderson, Lee G. 1993. "Toward a Complete Economic Theory of the Utilization and Management of Recreational Fisheries." *Journal of Environmental Economics and Management* 24 (3): 272–95.

Anderson, Leif E., and S. Todd Lee. 2011. "Washington and Oregon Saltwater Sport Fishing Surveys: Methodology and Results." Seattle, WA: National Marine Fisheries Service.

Beggs, S., S. Cardell, and J. Hausman. 1981. "Assessing the Potential Demand for Electric Cars." *Journal of Econometrics* 17, 1–19.

Boxall, Peter C., Wiktor L. Adamowicz, Joffre D. Swait, Michael Williams, and Jordan Louviere. 1996. "A Comparison of Stated Preference Methods for Environmental Valuation." *Ecological Economics* 18 (3), 243–53.

Dillman, Don A. 2000. *Mail and Internet Surveys: The Tailored Design Method.* New York: John Wiley and Sons.

Drake, J., E. A. Berntson, J. M. Cope, R. G. Gustafson, E. E. Holmes, P. S. Levin, N. Tolimieri, R. S. Waples, S. Sogard, and G. D. Williams. 2010. *Status Review of Five Rockfish Species in Puget Sound, Washington: Bocaccio (*Sebastes paucispinis*), Canary Rockfish (*S. pinniger*), Yelloweye Rockfish (*S. ruberrimus*), Greenstriped Rockfish (*S. elongatus*), and Redstripe Rockfish (*S. proriger*).* U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-108.

Endangered and Threatened Wildlife and Plants: Threatened Status for the Puget Sound/Georgia Basin Distinct Population Segments of Yelloweye and Canary Rockfish and Endangered Status for the Puget Sound/Georgia Basin Distinct Population of Bocaccio Rockfish, 74 75 Fed. Reg. 22276. 2010 (to be codified as 50 C.F.R. pts. 223–224).

Hall, Martin A., Dayton L. Alverson, and Kaija I. Metuzals. 2000. "By-catch: Problems and Solutions." *Marine Pollution Bulletin* 41 (1–6): 204–19.

Hanemann, W. Michael. 1991. "Willingness to Pay and Willingness to Accept: How Much Can They Differ?" *American Economic Review* 81 (3): 635–47.

———. 1999. "Welfare Analysis with Discrete Choice Models." In *Valuing Recreation and the Environment,* ed. Joseph Herriges and Catherine Kling. Northampton, MA: Edward Elgar, 33–64.

Harrington, Jennie M., Ransom A. Myers, and Andrew A. Rosenberg. 2005. "Wasted Fishery Resources: Discarded By-catch in the USA." *Fish and Fisheries* 6 (4): 350–61.

Jarvis, Erica T., and Christopher G. Lowe. 2008. "The Effects of Barotrauma on the Catch-and-release Survival of Southern California Nearshore and Shelf Rockfish (Scorpaenidae, *Sebastes* spp.)." *Canadian Journal of Fisheries and Aquatic Sciences* 65 (7): 1286–96.

Love, Milton S., Mary M. Yoklavich, and Lyman Thorsteinson. 2002. *The Rockfishes of the Northeast Pacific.* Berkeley: University of California Press.

McFadden, Daniel. 1974. "Conditional Logit Analysis of Qualitative Choice Behavior." In *Frontiers in Econometrics*, ed. Paul Zarembka, 105–142. New York: Academic Press.

Murawski, Steven A. 2000. "Definitions of Overfishing from an Ecosystem Perspective." *ICES Journal of Marine Science* 57 (3): 649–58.

National Marine Fisheries Service (NMFS). 2008. *Preliminary Scientific Conclusions of the Review of the Status of Five Species of Rockfish: Bocaccio* (Sebastes paucispinis), *Canary Rockfish* (Sebastes pinniger), *Yelloweye Rockfish* (Sebastes ruberrimus), *Greenstriped Rockfish* (Sebastes elongatus) *and Redstripe Rockfish* (Sebastes proriger) *in Puget Sound, Washington.* Seattle, WA: National Marine Fisheries Service.

Palsson, Wayne A., Tien-Shui Tsou, Greg G. Garbmann, Raymond M. Buckley, Jim E. West, Mary L. Mills, Yuck Wing Cheng, and Robert E. Pacunski. 2009. *The Biology and Assessment of Rockfishes in Puget Sound.* FPT 09-04. Olympia: Washington Department of Fish and Wildlife.

Parker, S. J., S. A. Berkeley, J. T. Golden, D. R. Gunderson, J. Heifetz, M. A. Hixon, R. Larson, B. M. Leaman, M. S. Love, J. A. Musick, V. M.

[25] While beyond the scope of this article, an interesting direction for future research would be to examine the full life cycle of rockfish conservation costs by linking the model presented here with a biological model, providing the framework necessary to understand the trade-offs between the time necessary to rebuild rockfish populations and the resulting economic costs.

O'Connell, S. Ralston, H. J. Weeks, and M. M. Yoklavich. 2000. "Management of Pacific Rockfish." *Fisheries* 25 (3): 22–30.

Parker, Steven J., Howard I. McElderry, Polly S. Rankin, and Robert W. Hannah. 2006. "Buoyancy Regulation and Barotrauma in Two Species of Nearshore Rockfish." *Transactions of the American Fisheries Society* 135 (5): 1213–23.

Poe, Gregory L., Kelly L. Giraud, and John B. Loomis. 2005. "Computational Methods for Measuring the Difference of Empirical Distributions." *American Journal of Agricultural Economics* 87 (2): 353–65.

Randall, Alan, and John R. Stoll. 1980. "Consumer's Surplus in Commodity Space." *American Economic Review* 70 (3): 449–55.

Scrogin, David, Kevin Boyle, George Parsons, and Andrew J. Plantinga. 2004. "Effects of Regulations on Expected Catch, Expected Harvest, and Site Choice of Recreational Anglers." *American Journal of Agricultural Economics* 86 (4): 963–74.

Small, Kenneth A., and Harvey S. Rosen. 1981. "Applied Welfare Economics with Discrete Choice Models." *Econometrica* 49 (1): 105–30.

Tolimieri, Nick, and Phillip S. Levin. 2005. "The Roles of Fishing and Climate in the Population Dynamics of Bocaccio Rockfish." *Ecological Applications* 15 (2): 458–68.

Train, Kenneth. 2003. *Discrete Methods with Simulation.* Cambridge, UK: Cambridge University Press.

Waples, R. S. 1991. "Pacific Salmon, *Oncorhynchus* spp., and the Definition of 'Species' under the Endangered Species Act." *Marine Fisheries Review* 53 (3): 11–22.

Washington Department of Fish and Wildlife (WDFW). 2010a. *Fishing in Washington, 2010/2011.* Sportfishing Rules Pamphlet. Olympia: Washington Department of Fish and Wildlife.

———. 2010b. *Revised Draft Environmental Impact Statement for the Puget Sound Rockfish Conservation Plan.* Olympia: Washington Department of Fish and Wildlife.

———. 2011. *Fishing in Washington, 2011/2012.* Sportfishing Rules Pamphlet. Olympia: Washington Department of Fish and Wildlife.

Williams, Gregory D., Phillip S. Levin, and Wayne A. Palsson. 2010. "Rockfish in Puget Sound: An Ecological History of Exploitation." *Marine Policy* 34 (5): 1010–20.

Woodward, Richard T., and Wade L. Griffin. 2003. "Size and Bag Limits in Recreational Fisheries: Theoretical and Empirical Analysis." *Marine Resource Economics* 18 (3): 239–62.

Yeh, Chia-Yu, Timothy C. Haab, and Brent L. Sohngen. 2006. "Modeling Multiple-Objective Recreation Trips with Choices over Trip Duration and Alternative Sites." *Environmental and Resource Economics* 34 (2): 189–209.

Zwerina, Klaus, Joel Huber, and Warren F. Kuhfeld. 2005. "A General Method for Constructing Efficient Choice Designs." SAS Institute Paper TS-722E. Cary, NC: SAS Institute.