Effects of Regulations on Expected Catch, Expected Harvest, and Site Choice of Recreational Anglers

David Scrogin, Kevin Boyle,
George Parsons, and Andrew J. Plantinga

The use of public lands and waterways is often subject to environmental regulations designed to limit the depletion of resource stocks. Such regulations may influence expectations of quality, destination choice, and consumer surplus. This paper examines the effects of environmental regulations on recreational anglers. The empirical application develops a joint model of expected catch and expected harvest in conjunction with a random utility model of site choice. Findings for Maine anglers indicate that regulations have sizable effects on catch and harvest, site choice, and welfare.

Key words: consumers, fisheries, nonmarket valuation, recreation demand, regulations.

The use of public lands and waterways is often subject to environmental regulations designed to limit the depletion of resource stocks. A prevalent example with international significance is the regulation of commercial and recreational fishing. Regulations such as quotas and gear restrictions are adopted by agencies to correct or deter excessive stock depletion and derive largely from biological, rather than economic, objectives. Regardless of the objectives guiding regulators and of whether commercial or recreational fishing is of interest, variation in the stringency of regulations over species and geographic areas may influence expectations of the variety and quantity of species to catch and harvest and the choice of site to access. Further, changes in the mixture of regulations may impact the benefits derived from commercial and recreational fishing.

Fishing regulations affect resource stocks by altering the quantities caught and harvested. While the regulation of commercial fishing has received considerable attention, the economic consequences of regulations imposed upon recreational fishing remain underinvestigated despite the allocation of sizable resources to agencies to manage marine and freshwater stocks. Typically, regulations are readily observed site attributes—by recreationists and researchers—thus lending themselves naturally to inclusion in models of recreation demand. Considering the attention given in the literature to nonmarket demand and benefits estimation and ongoing debates on the use and management of public lands and waterways, the limited attention given conceptually and empirically to regulations is surprising. Therefore, as light is only beginning to be cast upon the implications of environmental regulations for consumers, in general, and recreationists, in particular, we tackle the issue in the context of recreational fishing.

The paper is organized as follows. In the next section we develop a model of a utility-maximizing consumer confronting a choice set

David Scrogin is assistant professor, Department of Economics, University of Central Florida. Kevin Boyle is Libra Professor of Environmental Economics, Department of Resource Economics and Policy, University of Maine. George Parsons is professor, Department of Marine Policy, University of Delaware. Andrew J. Plantinga is assistant professor, Department of Agricultural and Resource Economics, Oregon State University and fellow, Rural Development Research Consortium.

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comprised of regulated and unregulated alternatives. Regulations enter the indirect utility function *directly* as attributes of the destinations and *indirectly* through individual expectations of quality, such as anticipated numbers of fish caught and harvested. In the section "Models of Regulated Site Choice" a joint model of expected catch, expected harvest, and site choice is estimated for Maine freshwater anglers. Our approach is consistent with the structure of many systems of recreational regulations. First, because regulations may vary between species, catch and harvest expectations are modeled for a collection of species. Second, because certain regulations target catch and others target harvest and considering the dependence of harvest upon catch, angler expectations of catch and harvest are jointly modeled. The approach also permits the effects of catch and harvest determinants to vary between species and catch and harvest expectations to enter demand models in a variety of ways. Welfare estimates from amendments to the regulations portfolio and the policy implications of the results are discussed in the section "Models of Regulated Site Choice." The last section concludes.

Regulating Recreationists

Perhaps the earliest instrument to be extensively used to regulate recreation on public lands and waterways was restricting hunting and fishing privileges to license holders. Licensing provides managing agencies with a simple means of monitoring public pressures on the natural environment. For many recreational activities, including fishing and hunting, river rafting, hiking, site seeing, and camping, unlimited numbers of licenses are available. Alternatively, when quotas limit the number of licenses issued, access may be rationed by lottery, queue, or auction. In addition to granting access, licenses commonly restrict the activities in which the public may engage.

Although the objectives and constraints facing regulators may differ between jurisdictions, similarities exist in the types of regulations that agencies adopt. We categorize regulations into three groups and discuss them in a recreational fishing context. *General* regulations do not target angler catch or harvest, but instead restrict the activities of all types of recreationists; examples include restrictions on boat use and vehicle access. Alternatively, *catch* and *harvest* regulations target anglers. Catch regulations are designed to influence the likelihood of catching fish in order to reduce the occurrence of "hooking mortality" and other forms of premature death, yet they do not target particular species; examples include restrictions on the types of gear and bait that may be used and the number of lines that one may have simultaneously in the water. In a production context, catch regulations dictate the use of relatively inefficient inputs since a given quantity of regulated inputs (e.g., capital and time) yields lower outputs (i.e., catch and harvest) than is produced with a comparable amount of unregulated inputs (see Karpoff and Wilen for discussion of such catch regulations in the case of commercial fishing). Unlike general regulations and catch regulations, harvest regulations target particular species. Bag limits and length restrictions are harvest regulations commonly used to restrict, respectively, the numbers and sizes of fish that may be kept.[1]

When coupled with monitoring and sufficiently stringent penalties, regulations may influence individual behavior; and to the extent that regulations affect resource stocks, they may also signal site quality to the angler. Considering the regulations taxonomy discussed above, in a recreation demand framework regulations appear in the recreationist's utility-maximization problem directly as site characteristics and indirectly through catch and harvest expectations.

The Behavioral Model

License-holding anglers are assumed to have access to J sites (e.g., lakes and streams) that are characterized by a vector $\boldsymbol{Q}$ of natural and man-made attributes of the sites and general, catch, and harvest regulations denoted by R. On a given occasion, an angler may access a single site $j \in J$ to catch fish, some of which might be kept (i.e., harvested). Subject to budget and harvest constraints, the individual maximizes utility defined over the quantity of

[1] It is important to note that, in contrast to recreational fishing, the distinction between catch and harvest is often ambiguous with recreational hunting as a catch usually implies a harvest. Further, managing agencies often restrict catch—and thus harvest—to a single unit over a season or even a lifetime as stock regeneration with terrestrial species may occur at a slower rate relative to aquatic species. The modeling implication is that expected harvest will enter the recreationist's utility function as a probability.

fish caught (C) and harvested (H), a composite numeraire good (K), attributes of the sites, and catch and harvest regulations. Formally, the angler's maximization problem conditional on a trip to site j is represented as

$$(1) \quad \max_{H_j} U(C_j, H_j, I - P_j, Q_j, R_j) \quad \text{subject to} \quad H_j \leq \bar{H}_j$$

where I and P_j are, respectively, income and the implicit price of site access (e.g., travel costs and license fees), and $I - P_j$ defines the quantity of the numeraire good consumed. $\bar{H}_j$ bounds harvest from above: it may simply be equal to the quantity caught or be strictly less than the quantity caught if harvest regulations are in effect.

When an angler makes the site choice decision, the catch—and, hence, the utility-maximizing harvest—are unknown. We assume the angler has prior information about the catch distribution at each site and denote as $f_j(C)$ the discrete probability density defined over integers ranging from 0 to $\bar{C}_j$, an upper limit on catch (e.g., the stock of fish at site j). The optimal harvest for each possible catch is determined according to the harvest function

$$(2) \quad H_j^*(C_j, \bar{H}_j) = \operatorname*{argmax}_{H} U(C_j, H_j, I - P_j, Q_j, R_j) \quad \text{subject to} \quad H_j \leq \bar{H}_j.$$

Then, expected utility at site j may be computed as

$$(3) \quad EU_j = \sum_{C=0}^{\bar{C}_j} U\big(C_j, H_j^*(C_j, \bar{H}_j), I - P_j, Q_j, R_j\big) f_j(C).$$

A risk-neutral angler is concerned only with the expected values of random variables, in this case catch and optimal harvest. For the risk-neutral angler, it follows that

$$(4) \quad EU_j = U(EC_j, EH_j, I - P_j, Q_j, R_j).$$

As the catch and harvest expectations are individual-specific site attributes, the angler's site choice problem may be rewritten in the conventional way in terms of indirect utility:

$$(5) \quad \max_{j \in J} V(EC_j, EH_j, I - P_j, Q_j, R_j)$$

where EH_j is the expected *optimal* harvest.

Changes in policy affecting resource-based recreation generally appear through the portfolio of regulations (R_j) faced by the recreationist. Amendments to general regulations impact all recreationists. For example, the imposition of regulations on boat use constrains the boater population, which is comprised of anglers and nonanglers. Further, changes in boater behavior may affect the recreational experience of nonboaters. The compensating surplus (CS) from a change in a general regulation at site j is given by

$$(6) \quad V\big(EC_j, EH_j, I - P_j, Q_j, R_j^0\big) = V\big(EC_j, EH_j, I - P_j - CS, Q_j, R_j^1\big).$$

The superscripts distinguish the status quo portfolio of regulations (0) from the amended portfolio (1). The compensating surplus is the incremental income that maintains the individual at the original utility level. If changes in general regulations increase (reduce) utility, then all else being constant, the welfare change and CS are positive (negative). As with general regulations, changes in catch and harvest regulations directly affect utility through R_j, but the changes also affect utility indirectly through the catch and harvest expectations. From (5), the CS for a change in catch or harvest regulations at site j may be represented:

$$(7) \quad V\big(EC_j^0, EH_j^0, I - P_j, Q_j, R_j^0\big) = V\big(EC_j^1, EH_j^1, I - P_j - CS, Q_j, R_j^1\big).$$

If the policy change is associated with lower (greater) levels of catch or harvest and, all else being constant, is undesirable (desirable) relative to the status quo, then welfare is reduced (increased) and CS is negative (positive). Alternatively, the sign of CS may be ambiguous if the direction of the effects on utility differ.

Because consumer preferences and expectations of site quality may vary within the population, the implications of regulations for demand and welfare are open empirical issues. The following two sections explore, respectively, the demand and welfare effects of regulations with a rich survey data set comprised of Maine angler site choices, regulations, and catch and harvest of a variety of species. While examining recreationist preferences for regulations is of particular interest, we develop a joint model of species-specific catch and harvest expectations for completeness.

Models of Regulated Site Choice

Discrete choice random utility models (RUMs) have emerged as the preferred statistical tool for nonmarket demand and benefits analysis, and recreational fishing is no exception. Notable attention has been given to estimating RUMs with individual-specific catch expectations because the quantity and variety of species to catch are natural indicators of site quality (McConnell, Strand, and Blake-Hedges; Hausman, Leonard, and McFadden; Morey and Waldman 1998, 2000; Train, McFadden, and Johnson).

Angler-specific catch expectations commonly appear in recreation demand studies in one of the two fashions: at the species level (e.g., Atlantic Salmon) or as an aggregate of multiple species. While data limitations may necessitate the use of aggregate models of expected catch, species level modeling avoids biases associated with aggregated data and allows species-specific marginal effects to be estimated.[2] However, studies that employ species-level data have frequently used only a single species of fish despite the common presence of a variety of species in public waters. In this case, relevant explanatory variables may be omitted and other biases introduced in the process.

Although aggregate models of expected catch may suffer from aggregation biases, they involve multiple species. But, while species-level models may overcome the limitations of models that employ aggregate data, omitted variables bias may contaminate the results if expected catch is limited to a single species. The solution to the dilemma is to include catch expectations for a variety of individual species. A similar argument may be made with respect to the harvest expectations. Moreover, the dependence of harvest upon catch necessitates joint modeling of the process.

The Modeling Approach

Models of species-specific expected catch and expected harvest and the probability of site choice are sequentially estimated by maximum likelihood. Estimation involves the followings steps. First, a joint model of expected catch and expected harvest is estimated separately for four species of fish: the coldwater species, landlocked salmon and brook trout; and the warmwater species, striped bass and white perch. As quantities caught and harvested are nonnegative integers and the latter is dependent upon the former, a two-stage quasi-maximum likelihood (2SQML) count data estimator is used to model reported catch and harvest (see Cameron and Trivedi for background on count data models and Mullahy for details on 2SQML). Estimated zero-inflated Poisson (ZIP) models are used to generate catch and harvest expectations at the lakes and ponds comprising angler choice sets.[3] At the second stage, RUMs of site choice are estimated conditional upon the first stage estimates.

With the ZIP, the probability that angler i's catch (or harvest) at site j of species s, denoted by $Y_{i,j,s}$, is either zero or a positive integer is given, respectively, by

$$(8) \qquad \begin{aligned} &\text{prob}[Y_{i,j,s} = 0] \\ &\quad = \theta_{i,j,s} + (1 - \theta_{i,j,s})e^{-\mu_{i,j,s}} \\ &\text{prob}[Y_{i,j,s} = a] \\ &\quad = (1 - \theta_{i,j,s})\frac{e^{-\mu_{i,j,s}}\mu_{i,j,s}^{a}}{a!} \\ &\qquad\qquad\qquad a = 1, 2, 3, \ldots \end{aligned}$$

The term $\theta_{i,j,s}$ denotes the proportion of zeros and is treated as a latent random variable, and $\mu_{i,j,s}$ is the mean and variance of the Poisson distribution. Both are conditioned upon explanatory variables and parameters to be estimated. Defining $z_{i,j,s}$ and $x_{i,j,s}$ as vectors of regressors and α and β as parameter vectors, nonnegativity of $\theta_{i,j,s}$ and $\mu_{i,j,s}$ is ensured by specifying the former as a logistic transformation of $z'_{i,j,s}\alpha$ and the latter as an exponential function of $x'_{i,j,s}\beta$.[4] The log-likelihood function

[2] Biases may still result despite species-level modeling. For example, the survey instrument may elicit catch at a site over a season rather than per trip, yielding aggregates by species. Alternatively, catch data obtained on a per-trip basis are often limited to only part of a season, leading to possible biases when aggregating to seasonal or annual levels.

[3] Several models were initially examined, including the Poisson and negative binomial (type II) models and zero-inflated versions of the Poisson and negative binomial models. The zero-inflated models accommodate frequencies of zeros exceeding those attributable to the underlying distributions by modeling the probability of a positive outcome and allow the effects of regulations to be measured. The ZIP is selected as the zero-inflated negative binomial failed to converge in all cases, and it outperformed the standard Poisson and negative binomial models.

[4] However, any valid cumulative density function may replace the logistic transformation (e.g., the standard normal cumulative density leads to the probit model).

of the ZIP model is

$$(9)\quad \ln(L) = \sum_{i=1}^{n} 1(y_{i,j,s} = 0)\ln(\exp(z'_{i,j,s}\alpha) + \exp(-\exp(x'_{i,j,s}\beta))) + \sum_{i=1}^{n}(1 - 1(y_{i,j,s} = 0)) \times (y_{i,j,s}x'_{i,j,s}\beta - \exp(x'_{i,j,s}\beta)) - \sum_{i=1}^{n}\ln(1 + \exp(z'_{i,j,s}\alpha))$$

where the term $1(y_{i,j,s} = 0)$ is a binary variable that takes a value of 1 if $y_{i,j,s}$ is 0 and a value of 0 otherwise, and n is the total number of angler/site combinations. Predicted values obtained from the fitted models of catch are substituted into the harvest models for estimation.[5] Species-specific catch and harvest expectations may then be generated for individual anglers from the estimated models for the second stage analysis of site choice.

For the estimation of the site choice models, angler i's indirect utility function is expressed as the sum of deterministic and random components:

$$(10)\quad V_{i,j} = v(EC_{i,j}, EH_{i,j}, I_i - P_{i,j}, Q_j, R_j, A_i) + \varepsilon_{i,j} \qquad \forall j \in J.$$

The deterministic component of utility, $v(\cdot)$, is a function of expected catch and expected harvest, net income, the implicit price of accessing the site (e.g., travel cost and the opportunity cost of time), natural and man-made attributes of the site, and angler characteristics (A_i). The term $\varepsilon_{j,i}$ is the utility component that is unobserved by the researcher, but which is assumed to have a known distribution. The probability that angler i selects site j from the set of J sites may then be written as

$$(11)\quad \text{prob(choose } j) = \text{prob}[v(EC_{i,j}, EH_{i,j}, I_i - P_{i,j}, Q_j, R_j, A_i) + \varepsilon_{i,j} \geq v(EC_{i,f}, EH_{i,f}, I_i - P_{i,f}, Q_f, R_f, A_i) + \varepsilon_{i,f}] \quad \forall j, f \in J; \quad j \neq f.$$

Distributional assumptions about the random component lead to alternative RUMs. We adopt McFadden's conditional logit model, which results from assuming the ε's are i.i.d. type-I extreme value. Expression (11) may then be written in closed-form as

$$(12)\quad \text{prob(choose } j) = \frac{e^{v_{i,j}}}{\sum_{j=1}^{J} e^{v_{i,j}}} \quad \forall j \in J.$$

The deterministic utility component is expressed as a linear function of regressors ($x_{i,j}$) and parameters (β). The resulting conditional logit log-likelihood function is written as

$$(13)\quad \ln(L) = \sum_{i=1}^{I}\sum_{j=1}^{J} y_{i,j} \times \left(x'_{i,j}\beta - \ln\sum_{j=1}^{J}\exp(x'_{i,j}\beta)\right)$$

where the variable $y_{i,j}$ takes a value of 1 if individual i selects site j and is 0 otherwise. Maximizing (13) with respect to β yields the maximum likelihood estimates.

The Data

A rich data set obtained from initial and follow-up surveys of freshwater anglers in Maine is employed (see MacDonald, Boyle, and Fenderson for detailed discussion of the surveys and data). The surveys elicited angler preferences for various regulations-related inputs to catching fish, the sites visited, catch and harvest of ten species of fish, targeting of the species at the sites, and socioeconomic characteristics. The sample contains 164 Maine residents who took 1,827 single-day trips to 290 lakes and ponds. The four species of fish included in the analysis (salmon, trout, bass, and perch) comprise the bulk of reported catch and harvest.

The general, catch, and harvest regulations were identified from the handbook of fishing regulations given to anglers at the time of

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[5] Using (2) and the catch distribution $f_j(C)$ for site j, the expected harvest is computed as $EH_j = \sum_{C=0}^{\bar{C}_j} H_j^*(C_j, \bar{H}_j) f_j(C)$. One approach for generating expected harvest is to model the observed harvest as a function of observed catch and then compute the expectation of harvest as above, where $f_j(C)$ is derived from the observed catch. However, in most cases we have too few observations to reliably estimate $f_j(C)$ for individual sites and species. A feasible alternative is to specify harvest as a function of expected catch, where the latter is derived from the entire sample of catch observations.

Table 1. Sample Proportions of Regulations Variables

	Expected Catch Models				Expected Harvest Models				Site Choice Models	
Variables	Salmon	Trout	Bass	Perch	Salmon	Trout	Bass	Perch	Salmon	Trout
Catch regulations										
No Live Bait	0.13	0.13	0.14	0.13	–	–	–	–	0.14	0.14
Fly Fishing Only	0.06	0.06	0.06	0.06	–	–	–	–	0.07	0.07
Harvest regulations										
Bag Limit	–	–	–	–	0.10	0.03	–	–	0.03	0.11
Length Limit	–	–	–	–	0.05	0.01	–	–	0.01	0.06
General regulations										
Motor Limit	–	–	–	–	–	–	–	–	0.01	0.01
No Motorboats	–	–	–	–	–	–	–	–	0.02	0.02
Sample size (N)	683	692	664	686	454	461	435	457	529,830	

license purchase and available online through the managing agency's website. The regulations had a long-standing history at the time the surveys were conducted.[6] In all cases the regulations are defined as dummy variables (table 1). The catch regulations include restrictions on the use of particular types of gear (Fly Fishing Only) and bait (No Live Bait). These enter the ZIP models and the RUMs through interactions with angler characteristics associated with catching fish. For inclusion in the RUMs, No Live Bait is interacted with the variables Lures, Worms, Dead Bait, and Live Bait, which measure the frequency of angler use of specific types of bait and tackle. Similarly, the regulation Fly Fishing Only is interacted with Flies, a scale variable measuring the frequency of angler use of fly-fishing gear and tackle. Responses were elicited through questions in the follow-up survey of the general form, "How often do you use [*gear* or *bait/tackle type*] when fishing?" Response scales for the five catch-related angler characteristics ranged from 1 (never) to 11 (always).

The harvest regulations include bag limits and length limits on salmon and trout. These enter the expected harvest equations as dummy variables and the RUMs through interactions with five variables reflecting harvest-related angler characteristics. Four are indicators of whether the species were targeted on the choice occasion; the variables (named Targeted) take a value of 1 if the angler targeted the species, and a value of −1 otherwise. The fifth variable, Recreation, is equal to 1 if the angler reported fishing solely for recreation, and is equal to −1 otherwise. The coding of Targeted and Recreation is used because the regulations are also binary, in which case standard zero-one coding leads to base cases (i.e., zeros) that reflect multiple outcomes.

Lastly, the general regulations at the sites include two restrictions on boat use (No Motorboats and Motor Limit). Similarly to the catch and harvest regulations, the general regulations enter the RUMs through interactions with angler characteristics. As the follow-up survey did not elicit information directly related to the general regulations, we use the variables Age and Male for the interactions; and because the general regulations do not target catch or harvest, they are excluded from the respective ZIP models.

Estimation Results

We focus initially upon the first-stage ZIP models of expected catch and expected harvest for the four species of fish (table 2). For brevity, attention is limited to the catch and harvest regulations. Considering the catch regulations, No Live Bait has a significant effect on catch; however, the directions of the effects differ across species. In contrast, Fly Fishing Only is significant in only one of the four cases (bass). As with the quantity caught, the regulations have mixed effects on the probability of catching fish. Considering the harvest equations, no significant difference in the quantity harvested is found between regulated and unregulated sites for either species; however, the probability of a positive harvest of trout is significantly

[6] All of the regulations were in place for at least two years prior to the survey period, mitigating concern over potential simultaneity of regulations and catch and harvest rates.

Table 2. Zero-Inflated Poisson Estimates of Expected Catch and Expected Harvest

	Salmon	Trout	Bass	Perch
Angler catch				
Modified Poisson				
No Live Bait	0.53**	−0.38***	0.57***	−1.09***
	(0.23)	(0.08)	(0.21)	(0.25)
Fly Fishing Only	0.42	−0.06	1.82***	−0.54
	(0.55)	(0.10)	(0.42)	(0.51)
Logit model of positive catch				
No Live Bait	−0.12	−0.45	0.88*	0.32
	(0.38)	(0.31)	(0.48)	(0.59)
Fly Fishing Only	1.03	−0.91**	1.78*	0.42
	(0.84)	(0.41)	(1.05)	(1.09)
Sample size	683	692	664	686
$\ln(L_{\max})$	−501.84	−949.03	−880.94	−1,041.14
$\ln(L_0)$	−935.03	−2,837.49	−1,807.93	−2,700.14
Angler harvest				
Modified Poisson				
Length Limit	−1.03	0.18	–	–
	(1.40)	(0.21)		
Bag Limit	−1.97	−0.36	–	–
	(1.65)	(0.23)		
Logit model of positive harvest				
Length Limit	−2.20	−1.07**	–	–
	(3.22)	(0.55)		
Bag Limit	−2.25	−0.95**	–	–
	(5.02)	(0.45)		
Sample size (N)	454	461	435	457
$\ln(L_{\max})$	−181.25	−291.05	−100.04	−239.93
$\ln(L_0)$	−251.94	−766.84	−156.27	−765.06

Notes: Variable definitions and summary statistics and the full set of estimation results are available in appendix. ***, **, and * denote significance at the 0.01, 0.05, and 0.10 levels, respectively. Standards errors are reported in parentheses.

lower at sites with either a bag limit or length limit.

Conditional upon the estimated ZIP models, the second stage RUMs of site choice are estimated with the catch and harvest regulations *included* in the ZIP models and with the regulations *excluded* from the ZIP models for comparison. Several specifications of the indirect utility function, $v(\cdot)$, were examined. Results are reported here from the "classic" heterogeneity specification, which includes regulations through multiplicative interactions with angler characteristics (see Swallow et al. and Morey and Greer-Rossmann).[7] Expected harvests appear as proportions of expected catch as some of the coefficients are sensitive to specification in levels.

Estimation results indicate that the catch and harvest parameters are more sensitive to the specification of the catch and harvest equations than to the indirect utility function. With regulations included in the ZIP models, the probability of site choice is found to be increasing significantly in the catch and harvest expectations (table 3). But, with regulations excluded from the ZIP models, the Bass and Perch coefficients become insignificant, and the harvest expectations have a noticeable change in sign in all cases but Trout. Comparing estimates across species, the effects of unit increases in catch and proportions harvested

[7] The other specifications included (*a*) travel cost, expected catch, and site-specific constants and (*b*) travel cost, expected catch, expected harvest, and site-specific constants. Both were rejected by likelihood ratio tests relative to the classic heterogeneity specification. An alternative for accommodating heterogenous preferences is a random parameters model (Train), which accounts for unobserved heterogeneity at the individual or group level. The classic and random parameters approaches may also be combined (Morey and Greer-Rossmann). While flexible, random parameters models require distributional assumptions to be imposed upon the unobserved heterogeneity. Consistency of the parameter estimates is also a concern as the number of random parameters rises.

Table 3. Conditional Logit Estimates of Angler Site Choice

Variable ($N = 529{,}830$)	Indirect Utility Parameters with Regulations in the Catch and Harvest Models	Indirect Utility Parameters without Regulations in the Catch and Harvest Models
Travel cost	−0.21***	−0.21***
	(0.01)	(0.01)
Expected catch		
Salmon	2.43***	3.42***
	(0.19)	(0.22)
Trout	0.40***	0.46***
	(0.05)	(0.05)
Bass	0.23***	0.05
	(0.06)	(0.06)
Perch	0.04*	−0.01
	(0.02)	(0.02)
Expected proportion harvested		
Salmon	1.06***	0.45*
	(0.26)	(0.26)
Trout	0.59***	0.68***
	(0.18)	(0.19)
Bass	1.00***	0.53
	(0.37)	(0.36)
Perch	0.60**	2.05***
	(0.28)	(0.31)
Catch regulation interactions		
Fly Fishing Only × Flies	0.57***	0.51***
	(0.13)	(0.12)
No Live Bait × Dead Bait	0.12***	0.14***
	(0.04)	(0.04)
No Live Bait × Lures	−0.15***	−0.17***
	(0.03)	(0.03)
No Live Bait × Worms	−0.04	−0.07*
	(0.04)	(0.04)
No Live Bait × Live Bait	−0.05	−0.04
	(0.05)	(0.05)
Harvest regulation interactions		
Salmon Bag Limit × Targeted	−0.97***	−1.05***
	(0.23)	(0.23)
Salmon Bag Limit × Recreation	−0.11	−0.08
	(0.18)	(0.18)
Salmon Length Limit × Targeted	1.52***	1.47***
	(0.35)	(0.33)
Salmon Length Limit × Recreation	0.90***	0.98***
	(0.28)	(0.28)
Trout Bag Limit × Targeted	0.99***	0.97***
	(0.18)	(0.18)
Trout Bag Limit × Recreation	−0.11	−0.10
	(0.15)	(0.15)
Trout Length Limit × Targeted	0.85***	0.75***
	(0.21)	(0.22)
Trout Length Limit × Recreation	−0.07	−0.23
	(0.19)	(0.19)
General regulation interactions		
Motor Limit × Male	11.01***	10.95***
	(0.72)	(0.72)
Motor Limit × Age	−0.05***	−0.05***
	(0.01)	(0.01)
No Motorboats × Male	10.85***	10.66***
	(1.95)	(1.95)
No Motorboats × Age	0.00	0.00
	(0.02)	(0.02)
Alternative-specific constants		
% significant coefficients out of 289 (p-value < 0.05)	55.4	48.4
ln(L)	−5,928.87	−5,849.41
Pseudo-R^2	0.43	0.44

Notes: The estimated site-specific constants are available in an appendix. ***, **, and * denote significance at the 0.01, 0.05, and 0.10 levels, respectively. Standard errors are reported in parentheses.

on utility are the greatest with Salmon and the least with Perch.

In contrast to the expected catch and expected harvest variables, the coefficients on the interaction variables combining regulations and angler characteristics are robust to the specification of the first-stage catch and harvest equations. Results indicate that preferences for regulations vary sizably across the sample of anglers. However, *greater* choice probabilities are associated with all three categories of regulations. Thus, to the extent that anglers heed the regulations, it follows that while the regulations may deter recreationists from undertaking particular activities, they may not discourage visitation; and as a result, agency objectives underlying adoption of new regulations or alteration of existing regulations may be achievable without having a negative impact on visitation.

In fact, some recreationists may prefer sites with particular regulations in place. As an example, while sites with the catch regulation Fly Fishing Only have a greater probability of being chosen relative to sites without the regulation, all else being constant, the probability of choosing such a site increases with the frequency of angler's use of fly-fishing gear and tackle (Flies). Similar findings also hold for all but one of the significant harvest regulation interactions (Salmon Bag Limit × Targeted) and for one of the four general regulation interactions (Motor Limit × Age). Lastly, about half of the 289 site-specific constants are statistically significant ($p < 0.05$) in both cases.

In summary, the results indicate that (*a*) several of the fishing regulations are significantly related to catch, harvest, and the probability of site choice; (*b*) regulations on recreational activities may be perceived as desirable attributes by some recreationists and as obstacles to be avoided by others; and (*c*) inclusion of regulations in models of expected catch and expected harvest may improve the performance of individual variables and the overall fit of recreation demand models. Because nonmarket values are attached to recreational opportunities, a natural question follows regarding the welfare effects of policy amendments appearing in the form of regulatory changes.

Regulations and Recreationist Welfare

In the process of mitigating pressures on the natural environment by altering or removing existing regulations or imposing new regulations, resource management agencies can influence the nonmarket benefits derived from access to public lands and waterways. With consumptive use recreation, such as fishing and hunting, regulations enter the recreationist's indirect utility function *directly* as site characteristics and *indirectly* through expectations of quality, such as the quantities of fish expected to be caught and harvested. The expected catch and harvest models coupled with the RUMs may be used to measure welfare changes resulting from changes in fishing regulations.

In exploring the welfare effects of changes in fishing regulations, the interests are twofold. The first objective is to measure the benefits of increasing expected catch. While changes in catch may be the product of regulatory change, their effects are examined separately. Changes in expected catch for the coldwater group (salmon and trout) and the warmwater group (bass and perch) are evaluated. The second, and primary, objective is to measure the welfare effects of changes in general, catch, and harvest regulations. As public pressures relative to management efforts may lead to the removal of regulations at some or all of the sites, or instead to the closure of regulated sites, the heterogenous preference specifications of indirect utility may be used for estimating welfare changes across angler groups for the two contrasting scenarios. Similar to the RUM analysis (table 3), the estimated welfare changes are compared with regulations included and excluded from the ZIP models of expected catch and expected harvest.

In all cases, the compensating surplus (CS) derived by individual i from a change in a characteristic of site j is calculated as

$$(14) \quad CS = -\frac{1}{\beta_{TC}}\left[\ln\sum_{i=1}^{J} e^{v^0_{i,j}} - \ln\sum_{i=1}^{J} e^{v^1_{i,j}}\right]$$

where $v^0_{i,j}$ and $v^1_{i,j}$ denote indirect utility before and after the change, respectively, β_{TC} is the parameter on the variable Travel Cost, and J denotes the set of 290 sites. In the case of regulated site closures, J is reduced appropriately.

Consider first the estimated changes in welfare that result from increases in expected catch (table 4). Results indicate that the average estimated CS per trip for the increase in expected catch differs between the model that includes regulations at all stages and the model that excludes regulations from the catch and harvest equations, especially for the warmwater species group. This latter finding may be

Table 4. Compensating Surplus Estimates per Trip for Changes in Expected Catch

Scenario	Compensating Surplus (*CS*) with Regulations in the Catch and Harvest Models	Compensating Surplus (*CS*) without Regulations in the Catch and Harvest Models
25% increase in coldwater expected catch	\$2.01	\$2.74
	(2.21)	(3.03)
25% increase in warmwater expected catch	0.67	0.10
	(0.61)	(0.13)

Notes: Standard deviations are reported in parentheses.

attributed to the significant positive relations found between regulations and catch of bass (table 2). Further, changes in the average estimated surplus values differ between the species groups. The *CS* per trip is estimated to be about \$2.00 for the increase in catch of coldwater species and about \$0.70 per trip for the increase in catch of warmwater species.

With changes in the general, catch, and harvest regulations, the findings indicate that welfare increases, on average, only with the removal of harvest regulations; removal of the catch regulations and general regulations or closure of regulated sites lead to welfare losses on average (table 5). Considering the removal of the catch and harvest regulations, note that the results are sensitive to the specification of the underlying expected catch and harvest models. Removal of the catch regulations leads to relatively conservative welfare estimates when regulations are excluded from the expected catch and expected models, while the opposite occurs with the harvest regulations.

The sensitivity of the *CS* estimates is attributed to the suppression of the indirect effects of regulations contained in the catch and harvest expectations, which either add to or offset the direct effects that appear through the

Table 5. Compensating Surplus Estimates per Trip for Changes in Regulations

Regulatory Change	Compensating Surplus (*CS*) with Regulations in the Catch and Harvest Models	Compensating Surplus (*CS*) without Regulations in the Catch and Harvest Models
Catch regulations		
Removal of regulations		
No Live Bait	\$ − 2.59	\$ − 1.99
	(1.43)	(1.85)
Fly Fishing Only	−3.05	−2.76
	(1.10)	(1.56)
Harvest regulations		
Removal of regulations		
Bag Limits	1.07	2.76
	(1.89)	(1.98)
Length Limits	1.17	2.83
	(1.93)	(2.07)
Closure of regulated sites		
Bag Limits	−0.37	−0.37
	(0.63)	(0.67)
Length Limits	−0.20	−0.20
	(0.34)	(0.36)
General regulations		
Removal of regulations		
Motor Limit	−0.21	−0.21
	(0.60)	(0.60)
No Motorboats	−0.02	−0.02
	(0.07)	(0.08)

Note: Standard deviations are reported in parentheses.

regulation–angler characteristic interactions. For example, the regulation Fly Fishing Only was found to have a positive and significant effect on the probability of a positive catch and the quantity of fish (bass) caught (table 2), and a positive effect on the probability of site choice (table 3). It follows that the mean estimated *CS* for the removal of the regulation is larger when both effects are accounted for, rather than just the direct effect. The *CS* estimates are robust to the ZIP specifications for changes in the general regulations and closure of the regulated sites. The former is attributed to the general regulations being excluded from the expected catch and expected harvest models and the RUM estimates being robust with respect to the general regulation interaction variables; the latter is largely attributed to the large number of lakes and ponds that remain accessible upon closure of the regulated sites.

Two conclusions are as follows: First, while welfare losses might at first glance be associated with constraints imposed upon public access, prudent management of public resources may enhance welfare, at least for some individuals. Second, failure to recognize that regulations are characteristics of many nonmarket goods and that preferences may vary within a population will not only limit one's scope of study, but may also lead to incomplete, and potentially misleading, information for resource managers.

Conclusion

Regulations provide agencies with a variety of tools for managing activities on public lands and waterways. With recreational access, regulations derive largely from noneconomic objectives of state and federal planners. The impacts of regulations on natural resource stocks and environmental quality may be directly attributed to their effects on individual incentives, expectations of quality, and input and destination choices. In this article, regulations are found to have large and significant effects on angler catch, harvest, and site choice. As consumer preferences for regulations may vary within the population, a legitimate question is whether regulations are likely to be important empirically. The results of this study indicate that including regulations in recreation demand models has a greater impact on nonmarket benefit estimates than on the probability of site choice.

As a concluding note, ongoing debates on the use and management of public resources reveals that an array of constituents may be impacted by changes in regulatory policy. Further, heterogeneous preferences within the population may result in regulations being perceived as desirable attributes by some and obstacles to avoid by others. Therefore, since changes in the natural environment may result in, or from, changes in regulatory systems, we conclude that the characteristics of many nonmarket goods may need to be reconsidered in future demand analyses.

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