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Estimating Net Benefits of Reallocation: Discrete Choice Models of Sport and Commercial Fishing

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Abstract *Increasing conflicts over allocation have heightened interest among fishery managers in reliable and comparable measures of the relative economic contribution of commercial and sport fisheries. This paper shows how discrete choice methods may be applied to develop comparable estimates of net economic benefits of a proposal to reallocate sockeye salmon from the commercial to the sport fishery in Alaska's Kenai River. The study estimates net benefits that include both market and nonmarket use values for three groups of fishers: sport anglers, commercial drift and setnet operators, and their crew members. Results for a midrange scenario for run size and price suggest that the commercial losses roughly offset sport gains. However, the particulars of this fishery are key to this result. The principal advantages of the discrete choice method are the flexibility of a micro decision model and comparable treatment of time and intangibles across different user groups. The principal disadvantages are increased data requirements and the difficulty of estimating confidence intervals.*

Key words Allocation, commercial fishing, crew, discrete choice, net benefits, nonmarket value, recreational fishery valuation, salmon, sport fishing, travel cost model.

Introduction

Allocation between commercial and sport fisheries is becoming an increasingly difficult and divisive issue in fisheries management. As conflicts over allocation have increased, so has the interest in the relative economic contributions of commercial and sport fisheries. Fishery managers have sought to understand potential economic implications of reallocations, while sport and commercial fishing groups have attempted to demonstrate the economic importance of their respective fisheries.

While economists generally prefer net benefits to economic impact as a measure of economic effects (see Edwards 1990), the literature estimating net benefits for fisheries is limited. Travel cost and contingent value analyses have been conducted for several recreational fisheries. Accounting models have been used to estimate profits for commercial fisheries (see Gislasson 1996). We have found no studies, however, that attempt to use comparable methods to estimate the net economic ben-

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efits of reallocation between sport and commercial fisheries. Comparability issues arise from the nonmarket nature of the benefits of recreational angling, as well as from the difficulty of estimating the opportunity cost of time for both recreational and self-employed commercial fishers.

In this paper, we show how discrete choice methods may provide comparable estimates of net benefits of changes in salmon management for three quite different groups of users: sport anglers, commercial drift and setnet operators, and their crew members. We begin with an overview of the Kenai River sockeye salmon fisheries. We then introduce the general discrete choice model we use and discuss how one may use it to derive comparable estimate changes in economic welfare. We elaborate on the particulars of the model in separate sections for sport anglers, commercial operators, and crew. Following our summary of main results, we comment on the advantages and disadvantages of the methodology.

Kenai River Sockeye Salmon Fisheries

The Kenai River is one of several major salmon producing rivers flowing into Cook Inlet, a large bay of the Pacific Ocean located in southcentral Alaska. Millions of salmon return to Cook Inlet each year, including all five Pacific salmon species.

The volume and value of Upper Cook Inlet commercial harvests varies widely from year to year, depending on run size and ex-vessel prices. Between 1980 and 1984, the Upper Cook Inlet commercial harvest varied from less than 3 million to more than 15 million salmon, and the ex-vessel value ranged from less than $20 million to more than $100 million. In the 1990s, sockeye salmon accounted for more than 90% of the value of the Upper Cook Inlet commercial harvest. The late run of Kenai River sockeye, which occurs in late June and July, accounts for most of this sockeye harvest.

Entry to the Cook Inlet commercial salmon fisheries has been limited since the late 1970s. Seven hundred forty-five individuals hold setnet permits and 583 hold drift gillnet permits for the Upper Cook Inlet salmon fisheries. Alaska resident permit holders land about 86% of the total setnet harvest and 73% of the driftnet harvest.[1]

The Kenai River system is also Alaska's most popular salmon sport fishing area. The river has long been famous for its king salmon fishing, but the popularity of sockeye fishing has been growing. Between 1981 and 1994, estimated angler days fished on the Kenai River (for all species) increased from 179,000 to 341,000. The Kenai River is within easy driving distance of Anchorage, where nearly half of all Alaskans live. Sport fishing by nonresidents is also increasing. Sales of fishing licenses to nonresidents almost tripled between 1983 and 1994. Nonresidents accounted for about 56% of all households that fished the Kenai River in 1993 (ISER 1996, chap. II).

Most of the sockeye salmon sport fishing on the Kenai River occurs during the last two weeks in July and the first week in August. In recent years, the sport harvest of Kenai River sockeye has varied from less than 40,000 to more than 330,000 fish—and from 11% to 26% of the total number of sockeye reaching the river mouth.

The management of Upper Cook Inlet sockeye fisheries is complicated by the fact that salmon stocks from a number of rivers and streams mingle in the inlet; run sizes change dramatically and unpredictably from year to year; and runs are brief but intense, with millions of fish moving through the inlet within a period of weeks.

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[1] Calculated over the period 1990–93. Source: unpublished data, Alaska Commercial Fisheries Entry Commission.

The Alaska Board of Fisheries sets the target escapement into the Kenai River and spawning population goals. The Alaska Department of Fish and Game (ADFG) biologists regulate the time and location of commercial openings to achieve the target escapement to the Kenai and other rivers. They also regulate sport openings, gear, and bag limits to achieve spawning goals.

There have been many allocation conflicts between commercial and sport fisheries in Alaska. One of the most intense has been over the allocation of Kenai River sockeye salmon. At the time of the present study, the management target that was set by the Alaska Board of Fisheries was for escapement of 400,000 to 700,000 sockeye into the Kenai River. They were to be counted at the sonar 19 miles upstream from the river mouth. To assist the Board in its deliberations over revising the allocation formula, the Alaska legislature requested a study of the economic effects of increasing the target sonar count by 200,000 sockeye in order to improve catch rates and increase the harvest of recreational anglers. ADFG biologists estimated that sport anglers would catch 45,000 additional sockeye and 500 more king salmon in the Kenai River and its tributaries. ADFG managers also provided assumptions about how the number of commercial openings and the resulting commercial harvests would change in order to meet the higher escapement target. Because the policy focus of the decision was at the state level, only net benefits to Alaska residents were included in the study.[2]

Estimating Welfare Changes from Discrete Choice Models

Economists have been using discrete choice models extensively to predict behavior and estimate economic value in the transportation literature for more than two decades (Ben-Akiva and Lerman 1985; Domencich and McFadden 1975). Applications to fisheries are relatively limited and relate primarily to recreational fisheries (see Bockstael, McConnell, and Strand 1989). Although specific characteristics of economic models of discrete choice vary across applications, all have a number of common attributes. McFadden (1981) provides a comprehensive discussion of the formal assumptions and theoretical properties of discrete choice models. The most important of these may be summarized as follows: (*i*) economic agents (consumers or firms) face a known set of alternative choices; (*ii*) the indirect utility of each choice, j, to the agent is the sum of a predictable component, V_j, and a random component ε_j uncorrelated with V_j;[3] and (*iii*) agents select the alternative from the available opportunities that has the largest expected indirect utility.

Often it is appropriate to assume that agents face a nested choice structure. That is, individuals first select among subsets of the alternatives, then they select an alternative from the chosen subset. In this case, the probability of selecting alternative j becomes conditional on selecting the subset—the branch of the decision tree—that

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[2] The full study (ISER 1996) includes analyses of changes in economic impacts of both fisheries as well as net benefits, under several sets of assumptions (scenarios) about prices, run size, fishery management, and other factors. ADFG and ISER together developed nine scenarios, or sets of key assumptions about key factors affecting changes in net economic value of the commercial or sport fishery, including the ex-vessel price, the run size, and sport fishery bag limits. Economic impacts and changes in net economic value were estimated for each scenario. The study also includes a contingent valuation analysis to estimate the net values of particular allocation measures.

[3] The Random Utility Model (RUM), a commonly used discrete-choice model, assumes that the "random" component is revealed to the agent—and therefore known—at the time the agent makes the choice (for example, weather conditions on a particular day the agent decides to go fishing). The "predictable" component of (indirect) utility, V_j, may depend on expected values of uncertain items such as prices and catch rates if agents are assumed to make decisions on these expected values, provided they vary independently of ε_j.

contains j. If alternative j is an element of the subset n with S_n choices, and if the random term, ε_j, has the type-one extreme value error structure, then the probability π_j that alternative j will be selected on a given choice occasion is:

$$\pi_j|n = \frac{e^{V_j/(1-\sigma_n)}}{\sum_{i=1}^{S_n} e^{V_i/(1-\sigma_n)}} \,; j = 1, 2, \ldots, S_n \tag{1}$$

A subscript for the time period (choice occasion) is implied in equation (1), but excluded for ease of exposition.

If there is only one level of the decision structure, the parameter σ in equation (1) is assumed equal to zero. If we instead assume a nested decision structure with N subsets of alternatives, then the assumption of the type-one extreme value distribution for ε_j allows one to write the probability of selecting a particular subset of choices n as:

$$\pi_n = \frac{e^{\varphi_n X_n + (1-\sigma_n) I_n}}{\sum_{m=1}^{N} e^{\varphi_m X_m + (1-\sigma_m) I_m}} \,; n = 1, 2, \ldots, N \tag{2}$$

where X_n represents a vector of characteristics that may vary across agents that affect their choices, and I_n represents the *inclusive value*, given by:

$$I_k = \ln \sum_{i=1}^{S_k} e^{V_{ik}/(1-\sigma_k)}; k = 1, 2, \ldots, S_k \tag{3}$$

The inclusive value, I_k, in equation (3) represents an index of the agent's perceived overall value of the set of choices available in branch k of the decision tree. The inclusive value, I_k, through its coefficient $1 - \sigma_k$ $(0 \leq \sigma_k \leq 1)$, provides the mechanism by which the quality of the S_k opportunities in subset k influences the probability of selecting branch k of the decision tree.

Small and Rosen (1981) show how one may derive estimates of compensating variation from discrete choice models that are analogous to those derived from standard aggregate demand and supply models. Given the indirect utility of each choice, V_j, the total indirect utility to the agent of all opportunities includes some contribution from options that were available, but not actually selected. If the marginal utility of income is a constant, and if income has a negligible effect on the probability selecting a given alternative, then the compensating variation associated with the availability of a particular choice j with utility v^1 is obtained as follows:

$$CV_j = \frac{1}{\lambda} \int_{-\infty}^{v^1} \mu_j(V_j) dV_j \tag{4}$$

where μ_j represents the (unconditional) probability of selecting alternative j, and λ equals the marginal utility of income, $\partial V/\partial y$.[4] For the nested logit model, the unconditional probability $\mu_j = \pi_n \pi_j$.

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[4] Equation (4) represents the limiting case of the compensating variation for a change in quality of the alternative from a quality that yields a zero probability of selection to the current quality attributes.

The Random Utility Model (RUM) (McFadden 1981) combines the assumptions of type-one extreme value distribution for ε_j, constant marginal utility of income, and negligible income effects.[5] We use variations of RUM to model demand and value for sport and commercial fisheries. McConnell (1995) shows that measuring consumer surplus, defined as

$$CS_j = \int_{p_j}^{\infty} \mu_j \left[V(p_j) \right] dp_j \tag{5}$$

where p_j represents the price of alternative j, is equivalent to measuring compensating variation as previously defined in equation (4) for RUM models.

Measuring Net Benefits for Sport Anglers

Travel Cost Model

We estimate the demand for fishing trips to the Kenai River and other sites by assuming a two-level nested choice structure. Angling households first decide whether to take a fishing trip (or more than one trip) during a given week or month. Then they choose their fishing site.

Following RUM, we assume that the nonstochastic component of utility V_j in equation (1) realized from selecting site j, given that the angler takes a sport fishing trip, is a linear function of its price, p_j:

$$V_j = \alpha(y - p_j) + \beta(1 - h)g_j + \left[\gamma_1 h + \gamma_2(1 - h)\right]t_j + \delta z_j \tag{6}$$

where y represents income; h is a dummy variable that is equal to one if the consumer can vary work hours, and equal to zero if work hours cannot be varied; g_j represents travel time to site j; t_j represents on-site time; and z_j is a vector of site characteristics representing the quality of the recreational experience.

The price of the trip to alternative j, p_j, is

$$p_j = p_j^n + p_j^* + p_j^t t_j + wh(g_j + t_j) \tag{7}$$

where p_j^n is the monetary cost of travel to the site, p_j^* represents on-site expenditures that do not vary with on-site time, and p_j^t represents expenditures incurred with an additional unit (hour) of on-site time. Equations (6) and (7) follow Bockstael, McConnell, and Strand (1989) by constraining the marginal opportunity cost of time to equal foregone marginal earnings for anglers who can vary their work time ($\beta = -\alpha w$ when $h = 1$).[6] Since total income, y, and total time do not vary across alternatives, no information is lost by excluding them from the estimated equation for V_j.

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[5] We follow McFadden's convention of additive separability of utility into a term depending on income and a term depending on the nonexpenditure attributes of the discrete choice.

[6] This specification allows for the possibility that on-site time is endogenous and varies across sites. McConnell (1992) has shown that it is not necessary to include on-site time directly in equation (1) to obtain consistent estimates of α and δ when on-site time is endogenous. Equations (6) and (7) are general forms that permit a variety of assumptions about on-site time. The specification of on-site time is of empirical significance in this study as described below.

In the upper level of the choice structure, anglers choose discrete categories of participation. We estimate two separate equations: one for frequent anglers (households expecting to take more than five fishing trips during the summer), and one for infrequent anglers. Frequent anglers choose whether to go fishing once, twice or more, or not at all during a particular *week*. Infrequent anglers choose between taking zero trips or at least one trip during a given *month*. Both groups of anglers choose from the same set of fishing sites for each trip.[7]

The participation equations represent special cases of equation (2). For frequent anglers the probability of choosing trip category m may be represented as follows:

$$\pi_m = \frac{e^{\varphi_m X_m + (1-\sigma_m) I_m}}{1 + e^{\varphi_1 X_1 + (1-\sigma_1) I_1} + e^{\varphi_2 X_2 + (1-\sigma_2) I_2}}\text{; } m = 1 \text{ trip, 2 or more trips} \qquad (8)$$

where I_m is given by equation (3). For infrequent anglers, equation (8) has only one term (for $m = 1$), but is otherwise similar.

Data

We obtained information about fishing trips and expenditures during the 1993 fishing season from a series of telephone and mail surveys completed by 550 southcentral Alaska sport fishing households.[8] Angling households provided detailed expenditure accounts on 1,298 sport fishing trips between May 1 and October 31. We divided the season into 27 weeks running from Thursday to Wednesday. In order to estimate the site choice equation, we grouped survey fishing trips into nineteen origin areas and thirty site destinations.[9]

The set of available alternative sites varied during the course of the 27 week season due to regulatory closures. To represent potential components of expected fishing quality, we utilized data on seasonal availability, peak fishing periods, regulatory openings, bag limits, published weekly fishing forecasts, and annual catch

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[7] We defined a household fishing trip to include a trip by any household member during the choice horizon. Survey responses showed that the frequency of fishing varied from one trip to over 100 trips per household during the six-month season. We used expected number of fishing trips in a pre-season interview rather than actual trips to divide anglers into frequent and infrequent categories in order to avoid potential selection bias arising from choosing the subsample based on values of the dependent variable.

[8] The southcentral households were part of a statewide survey of resident sport angling. A random digit dial algorithm was used to generate a sample of phone numbers from all the residential prefixes in the state. Households contacted were screened for sport fishing activity in the last three years or anticipated for 1993. The person interviewed was the person who knew the most about the household's fishing activities. The pre-season telephone survey in June 1993, had 1,355 responses—a response rate of 83%. The follow-up monthly mail surveys that collected trip information did not get an acceptable response, so the original panel was re-interviewed by phone in the fall of 1993. The fall survey elicited 918 completed interviews—a response rate for the panel of 68%.

[9] Southcentral Alaska affords an extremely large and heterogeneous set of sport fishing alternatives of varying quality. The decision to group locations into thirty alternatives was based on locations mentioned by survey respondents, data available on "site" characteristics, and researchers' judgment on the best way to represent the set of discrete independent alternatives actually available for angling households to select. The researchers are aware of the problem with estimating demand from aggregated alternatives with unequal numbers of separate choices (see Ben Akiva and Lehrman 1985) if anglers in fact are choosing among a larger number of independent alternatives. However, standard measures of size such as launch points or river miles are not available on most sites, and in any case cannot substitute for professional judgment in comparing thirty miles of a large, navigable river, to a series of adjacent small lakes and streams, or to ocean fishing.

rates for the prior year for fourteen species and species groups. We also included site-week dummy variables for major fishing derbies and an indicator provided by management biologists of seasonally crowded fishing conditions. In addition, we tested dummy variables for site amenities that differ among sites such as cabins, campgrounds, boat ramps, and services. The ADFG annual sport fish survey for 1992 (Mills 1993) provided data on annual catch and angler days at each site. Data for seasonal availability, peak fishing times, and fishing regulations were coded from ADFG brochures.[10]

Estimation Results

The site-choice equation takes the form specified in equation (1) using equation (6) to specify V_j, and equation (7) to specify the price of the trip. The estimation of V_j requires predicted values of foregone earnings and trip expenditures for all alternative sites, including sites not visited by a particular angler. We estimate predicted marginal earnings losses for travel and on-site time for trips to alternative sites with a regression equation used on reported trips. We assume constant marginal earnings losses per travel hour, or on-site hour, for all anglers who reported positive earnings losses for the fishing trip actually taken.

The trip cost variable is the sum of fuel cost, vehicle depreciation cost, other trip expenditures such as food, lodging, bait, and guide costs, as well as lost income for those who could have worked during their travel and on-site fishing time. We estimate nontransportation expenditures for trips to alternative sites from separate tobit equations estimated from survey fishing trips for spending on food, lodging, bait, and guides. Explanatory variables for the expenditure equations include site and household characteristics, travel time, and on-site time. On-site time at alternative sites is assumed to be endogenous. We use the unbiased predictions of a tobit equation for on-site time with right-hand-side variables consisting of the set of exogenous variables tested in the site-choice equation.[11] We use the resulting predicted values of on-site time, marginal lost earnings, and trip expenditures for all sites.

Table 1 shows the coefficients for V_j estimated from the multinomial logit site-choice equation. The coefficients in table 1 appear generally plausible, with trip cost and travel time (for anglers who could not have worked) coefficients negative and strongly significant. We estimate a structural equation for endogenous on-site time rather than the simpler "reduced-form" equation proposed by McConnell (1992). We take this approach to obtain more efficient estimates, since the specific policy change proposed—changing the allocation of Kenai River sockeye salmon—strongly affects the predicted on-site time to the Kenai River sites. A series of variables that represent quality of fishing for a variety of species have positive and significant coefficients. In addition, the equation suggests that anglers prefer uncrowded sites with campgrounds, and a popular derby fishery, other things being equal.

Table 2 shows the estimation results of the participation equations (8) for infrequent and frequent anglers. We tested independent variables (X) for household characteristics such as skill, income, number of anglers, and ownership of capital equip-

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[10] Readers interested in the details of variable construction, survey methods, and data sources for the study may consult ISER (1996).

[11] Coefficients for travel time, bag limits, fishing derbies, and availability of on-site tourist services were positive and significant in the on-site time equation, and coefficients for travel cost and foregone earnings were significant and negative. Overall, the null hypothesis of exogenous on-site time is easily rejected at a 1% significance level.

Table 1
Site-Choice Equations for Resident Anglers

Variable	Symbol	Coefficient	t-Statistic
Tripcost	$-\alpha/(1-\sigma)$	–0.00350	–7.34
Travtime	$\beta/(1-\sigma)$	–0.0928	–7.76
Nifhours	$\gamma_1/(1-\sigma)$	–0.169	–3.92
Yifhours	$\gamma_2/(1-\sigma)$	–0.0105	–0.20
Trout	$\delta_1/(1-\sigma)$	0.00504	2.66
Dolly	$\delta_2/(1-\sigma)$	0.00781	5.04
Kingdf	$\delta_3/(1-\sigma)$	1.554	7.06
Sockdf	$\delta_4/(1-\sigma)$	0.509	7.16
Kingrept	$\delta_5/(1-\sigma)$	0.100	5.58
Silver	$\delta_6/(1-\sigma)$	0.0183	6.43
Sockeye	$\delta_7/(1-\sigma)$	0.00470	4.42
Ksonar	$\delta_8/(1-\sigma)$	2.0	3.00
Pinkchum	$\delta_9/(1-\sigma)$	0.0302	2.177
Halipeak	$\delta_{10}/(1-\sigma)$	1.345	10.17
Troutbag	$\delta_{11}/(1-\sigma)$	0.156	8.39
Campgr	$\delta_{12}/(1-\sigma)$	1.725	1.81
Crowding	$\delta_{13}/(1-\sigma)$	–1.719	–1.69
Sewdby	$\delta_{14}/(1-\sigma)$	1.147	3.68
Observations		38,730	
Log-likelihood		–3,806.3	
Initial slopes = 0		–4,390.9	
Chi-squared		1,169.2	

Definitions:

Tripcosts_{it}	Trip cost to get to the *i*th site = fuel cost + other trip expenditures + vehicle depreciation cost + lost earnings for travel and on-site time for anglers who could have worked (instrumental variable for on-site time).
Travtime_i	Travel time to get to the *i*th site for those who could not have worked.
Nifhours_{it}	On-site fishing hours of anglers who could not have worked (instrumental variable).
Yifhours_{it}	On-site fishing hours of anglers who could have worked (instrumental variable).
Trout_i	Expected total annual catch for trout at the *i*th site (total harvest for previous year in thousands) when fishery is open, zero otherwise.
Dolly_i	Expected total annual catch for dolly varden at the *i*th site (total harvest for previous year in thousands).
Kingdf_i	Expected average fishing quality for king salmon at the *i*th site (total harvest divided by angler-days for the previous year at the *i*th site) when the fishery is open, zero otherwise.
Sockdf_i	Expected average fishing quality for sockeye salmon at the *i*th site (total harvest divided by angler-days for the previous year at the *i*th site) when the fishery is open, zero otherwise.
Kingrept_{it}	Fishing quality index for king salmon at the *i*th site that week as published in the *Anchorage Daily News*. The data are coded 0 to 6. Zero indicates closed or no report, while six indicates highest fishing quality.
Silver_i	Expected annual total catch for silver salmon at the *i*th site (total harvest for the previous year in thousands) when silvers are available and the fishery is open, zero otherwise.
Sockeye_i	Expected annual total catch for sockeye salmon at the *i*th site (total harvest for the previous year in thousands).
Ksonar_{it}	Sockeye salmon sonar count in thousands at Kenai River sites that week.
Pinkchum_i	Expected annual total catch for pink or chum salmon at the *i*th site (total harvest for the previous year in thousands) when pinks or chums are available and the fishery is open, zero otherwise.
Halipeak_{it}	Halipeak = 1, if halibut during weeks of peak halibut fishing at the *i*th site in week *t*, otherwise halipeak = 0.
Troutbag_{it}	Bag limit for trout at the *i*th site in week *t*.
Campgr_i	Campgr = 1, if a camp ground is available at the site, otherwise campgr = 0.
Crowding_{it}	Crowding = 1, if the *i*th site is crowded in week *t*, otherwise crowding = 0.
Sewdby_{it}	Sewdby = 1 for Resurrection Bay during the Seward silver salmon derby, otherwise sewdby = 0.

ment (boats and campers). We also tested variables indicating regional weather conditions. Information about fishing quality enters into the "inclusive value" (I), constructed from the site-choice equation.[12] The results suggest that angling households that own boats or campers, with higher fishing skills, and with more than two anglers in the household are more likely to take a fishing trip, other things being equal. Temperature, rainfall, and daylight hours also affect participation decisions in expected ways. The results for the two groups of anglers are similar, except that the coefficient on inclusive value, $1 - \sigma$, is somewhat lower for frequent anglers. That is, fishing conditions apparently influence participation of infrequent anglers in southcentral Alaska more than they influence participation of frequent anglers.

Welfare Effects of Management Changes

Consider two policy scenarios A and A', each with an associated set of site quality variables differing only for activity j. If the coefficient $1 - \sigma$ is the same for all branches of the decision tree that include choice j, then the compensating variation for the change may be derived directly from equations (1)–(4), (6), and (7) to yield:

$$CV_j^A - CV_j^{A'} = \frac{1}{\lambda}\left[\ln\left(1 + e^{\varphi X + (1-\sigma) I(V_j^A)}\right) - \ln\left(1 + e^{\varphi X + (1-\sigma) I(V_j^{A'})}\right)\right] \qquad (9)$$

where λ equals $-(1 - \sigma)$—the coefficient on inclusive value in table 2—times the estimated coefficient on trip cost (price) in table 1. Since the coefficients for $1 - \sigma$ for frequent anglers differ between the one-trip and two-or-more-trips alternatives, the integral in equation (4) does not have a closed-form solution, and numerical methods are required.[13]

For this study, the variables that changed with management scenarios for Kenai River sockeye were the sonar count and the sockeye and king salmon harvests at the four Kenai River sites.[14] Assumptions about how these would change under each scenario were supplied by management biologists. By far the most important variable is the sonar count in the Kenai River (*Ksonar*). Sonar count data is recorded daily during the sockeye run and is the key indicator of sockeye fishing quality used in weekly published and broadcast fish reports. A higher (or lower) fish count at the sonar contributes three quarters of the change in the compensating variation modeled in our scenarios.

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[12] For infrequent anglers, the inclusive value represents the average weekly inclusive value during that month.

[13] Hanneman (1985) discusses the conditions under which the integral in equation (4) has a closed-form solution when quality variables change simultaneously for two or more alternatives. The requirements include the conditions that the alternatives with changing quality collectively form a separate branch of the decision tree, and that they have the same estimate for λ. Note that equation (4) estimates the compensating variation for any change in exogenous variables affecting demand for site j, and does not rely on the assumption of weak complementarity between trip demand and on-site time.

[14] The specific model variables are *Ksonar*, *Sockeye*, *Sockdf*, and *Kingdf*. King salmon catch per angler day changes because restrictions on the commercial salmon fishery to increase escapement of sockeye salmon into the Kenai River would allow more King salmon past commercial nets. Other variables that might change are the fishing report for Kings (*Kingrept*) and crowding. Neither variable is precise enough to predict marginal changes, since Kenai River King salmon fishing is already excellent, and sites are already "crowded" during the weeks when fishing would change.

Table 2
Participation Equations for Frequent and Infrequent Anglers

Variable		Infrequent Anglers	Frequent Anglers	
		For Taking One or More Trips in Week *t*	For Taking One Trip in Week *t*	For Taking Two or More Trips in Week *t*
Constant	φ_0	−10.221	−9.624	−15.762
		(−13.48)	(−13.43)	(−10.59)
Incl	$1-\sigma$	0.536	0.149	0.510
		(4.19)	(1.42)	(2.89)
Boat	φ_1	0.555	−0.0449	0.420
		(4.93)	(−0.54)	(3.14)
Skill	φ_2	0.208	0.505	0.604
		(1.84)	(5.28)	(3.78)
Many	φ_3	0.280	0.323	0.488
		(2.28)	(3.80)	(3.65)
Anctemp	φ_4	0.0550	0.0746	0.0974
		(5.26)	(8.92)	(6.76)
Camper	φ_5	0.416		
		(2.20)		
Daylight	φ_6	0.186		
		(7.45)		
Avgearn	φ_7		−0.116	−1.534
			(−0.94)	(−3.70)
Avgreasn	φ_8		0.0109	0.0226
			(5.27)	(5.63)
Tg40_1	φ_9		0.275	0.346
			(3.85)	(2.02)
Wind20	φ_{10}		0–0.200	−0.301
			(−2.88)	(−2.81)
Pg10_1	φ_{11}		−0.161	−0.125
			(−4.73)	(−2.36)
Winter	φ_{12}		0.548	0.357
			(6.41)	(2.60)
Trips92	φ_{13}		0.00117	0.00762
			(1.02)	(6.12)
Observations		1,504	5,705	
Log–likelihood		−1,044.7	−2,979.5	
Initial (slopes = 0)		−1,248.3	−3,423.1	
Chi-squared		407.3	887.2	

Note: t-statistics are in parentheses.

Definitions:

Incl_t	Inclusive value representing overall fishing quality index in week *t* (sum of weekly inclusive values in the month for infrequent anglers).
Boat	Boat = 1, if the household owns a boat; otherwise boat = 0.
Skill	Skill = 1, if the household contains an experienced angler; otherwise skill = 0.
Many	Many = 1, if the number of anglers in a household exceeds 2; otherwise many = 0.
Avgearn	Annual average additional amount of income the household could have earned per trip by working instead of fishing, in thousands.
Avgreasn	Annual average percentage that fishing activities explains the purpose of the trip.
Tg40_1_t	Number of days that exceed the temperature of 40°F in week *t*.
Anctemp_t	Average Anchorage temperature during week or month *t*.
Wind20_t	Number of days that the wind speed exceeds 20 mph in week *t*.
Pg10_1_t	Number of days that precipitation exceeds 0.10 inches in week *t*.
Winter	Winter = 1, if the household took at least one fishing trip between the previous November 1 and April 30; otherwise winter = 0.
Trips92	Total number of fishing trips taken by an anglers between May 1 and October 31, 1992.
Camper	Camper = 1, if the household owns a recreational vehicle; otherwise camper = 0.
Daylight_k	Average hours of daylight in month *k*.

Measuring Net Benefits for Commercial Fishers

Net benefits from commercial salmon fishing potentially includes benefits to commercial fishing businesses, commercial fishing crew members, processing firms, workers, and consumers. Because of the competitive nature of the processing industry, the availability of close substitutes for Cook Inlet sockeye, and the fact that most of the harvest is exported, we presume that long-run net benefits for the processing sector and consumers would be small. Because the salmon fisheries are subject to limited entry, however, economic rents persist in the harvesting sector that could be affected by harvest reallocations.

We first describe how we measure benefits to commercial fishing business owner-operators (permit holders). Then we discuss net benefits to commercial fishing crew members. Permit holders are self-employed, and most crew are paid a share of gross revenues. For neither group is the opportunity cost of time directly measurable. We estimate the relevant opportunity costs indirectly using discrete choice methods that are closely analogous to the RUM model used for the sport fishery.

Observed Choices Model for Permit Holders

The observed choices model uses observations on the choices of individual firms among discrete alternative activities in order to estimate a profit function for the set of activities. Given a set of N potential alternative productive activities that a commercial fisher i can select during time period t, we model the nonstochastic component of utility from the activity as

$$V_{ijt} = V(p_{ijt} + y_i, q_{ijt}, Z_{ijt}) = \alpha\left[p_{ijt} + y_i - C(q_{ijt}, Z_{ijt})\right] \tag{10}$$

where y_i represents nonfishing income, less the fixed fishing costs that do not depend on which fishing activities are undertaken in period t; p_{ijt} now represents gross revenue from fishery j in time t; and C_{ijt} is a (short-run variable) cost function for that activity. Costs depend on harvest quantity, q, and a set Z of exogenous variables affecting fishing costs (cost-shift variables) that may vary among individuals as well as among fisheries.

Harvest quantity is a function of Z as well as the set X of characteristics of Cook Inlet salmon permit holders, and the boats and gear they own, that might affect their fishing costs in different activities: $q_{ijt} = f(X_i, Z_{ijt})$. We hypothesize a cost function for C_{ijt} that is a polynomial of up to degree three in q and linear in Z. Relative utility from equation (10) may be rewritten (ignoring the nonfishing income and fixed costs that do not vary across alternatives):

$$V_{ijt} = \alpha(p_{ijt} + \beta_1 q_{ijt} + \beta_2 q_{ijt}^2 + \beta_3 q_{ijt}^3 + \delta Z_{ijt}). \tag{11}$$

The observed choices model for Cook Inlet salmon fishing differs in some important ways from previous discrete choice models of commercial fishing estimated by Bockstael and Opaluch (1983), and Dupont (1993). Bockstael and Opaluch used survey data on accounting profits for typical fishing vessels over a five-year period to estimate commercial fishers' location choices as a function of expected wealth and variability of wealth. Dupont (1993) made estimates on the same basic model as the Bockstael and Opaluch model, but estimated profit functions from survey data on accounting revenues and accounting costs for individual vessels. In Dupont's model, "wealth" includes values of fishing licenses and expected profits, as well as fixed capital equipment.

Dupont, following Bockstael and Opaluch, assumed that the marginal utility of income was not constant, so she could test whether greater variability (or uncertainty) of expected profits in a fishery, due principally to price uncertainty, reduced utility. Her model thus violates one of the assumptions that allow us to use equation (4) for estimating compensating variation for policy changes. We are concerned with potential restrictions of choices during much shorter periods of time, during which prices are effectively known and constant across fishing areas. Commercial fishing operations plan their activities around scheduled openings and "emergency openings" that can be predicted to occur during the peak fishing weeks of the season. We therefore model the decision on whether or not to participate in the fishery on a weekly basis.

Although we observe ex-vessel prices, revenues, and harvest quantities, we have no information on accounting costs. Rather, we infer all "costs" including the subjective value of the commercial fisher's time by estimating equation (11). Data for fisheries participation, revenues from participation, and most X and Z variables are derived from the Alaska Department of Fish and Game landings, vessel license and permit data.

Model Estimation for Drift Fisheries

Because drift gillnet operations are mobile, we model them with a two-stage nested choice model. Drift captains first choose whether or not to participate in the Cook Inlet fishery during a given week. Then they select the area in which to fish. In this case, equation (1) represents the probability of selecting area j out of S area choices, given that the permit holder goes fishing that week. The participation equation uses the same variant of equation (2) as the participation equation estimated for infrequent sport anglers—that is, equation (8) with $m = 1$.

ADFG provided the schedule of fishery openings they posted for each district, as well as individual landing records of Cook Inlet drift permit holders (microdata) over a four-year period: 1990–93. We estimated regression equations to predict harvest quantity, q, and gross revenues, p, for each of the six areas. Right-hand variables include hours of fishing openings each week in each of the six fishing areas, vessel length and horsepower, and separate constant terms for each week and year.[15] Table 3 shows the complete statistical results for the area choice equation (1), with V_j given by equation (11). We estimated the equation using the predicted values of the quantity and gross revenue for all alternatives. The first two terms of the polynomial in q were significant. The equation suggests that incremental costs are slightly "U-shaped," rising when weekly harvests are large. Longer openings significantly increase profits, while costs rise with distance (miles) from the vessel's home port.

Table 4 shows complete statistical results for the participation equation. The inclusive value represents an index of weekly relative profits, so it does not include fixed costs. *Hours* represents the maximum fishing time available that week. *Length* and *hp* refer to length and horsepower of the vessel used by the permit holder for drift salmon fishing. Permit holders with larger vessels were more likely to go fishing for any expected maximum operating profit, possibly indicating the ability to fish profitably in less desirable weather conditions. Higher horsepower for the vessel diminished participation, possibly indicating higher overall operating costs.

Model Estimation for Setnet Fisheries

Setnet operators are restricted to a single fishing location. Instead of modeling fishing decisions as a nested choice of participation and fishing areas, we model a single-stage choice among several alternative activities, including fishing the setnet

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[15] Open hours were further divided into hours within and outside the three-mile inshore corridor for fishing areas along the east side of Cook Inlet near the outlet of the Kenai River.

Table 3
Coefficient Estimates for Choice of Fishing Area, Drift Permit Holders

Independent Variable	Coefficient Symbol	Estimated Coefficient	t-Statistic
revenue	$\alpha/(1-\sigma)$	0.514	27.27
quantity	$\alpha\beta_1/(1-\sigma)$	−0.438	−18.87
quantsq	$\alpha\beta_2/(1-\sigma)$	−0.00712	−16.48
log(hours)	$\alpha\delta_1/(1-\sigma)$	1.710	56.92
miles	$\alpha\delta_2/(1-\sigma)$	−0.0129	−23.65
Log likelihood	−18,999		
Initial (slopes = 0)	−22,846		
Number of observations	12,753		

Definitions:

revenue	Expected gross value in thousands of dollars landed in week *t*.
quantity	Expected quantity harvested (thousands of pounds of salmon) in week *t*.
quantsq	Quantity squared.
hours	Total number of hours any area was open for fishing in week *t*.
miles	Distance in miles from the fishing area to Homer (main fishing port).

Table 4
Equation for Participation Choice, Drift Permit Holders

Independent Variable	Coefficient Symbol	Estimated Coefficient	t-Statistic
constant	φ_0	−7.541	−62.79
hours	φ_1	0.00801	11.50
length	φ_2	0.0987	51.39
hp	φ_3	−0.267	−3.11
inclusive value	$1-\sigma$	0.568	33.75
Log likelihood	−14,739		
Initial (slopes = 0)	−20,342		
Number of observations	29,347		

Definitions:

constant	Constant term.
hours	Total number of hours any area was open for fishing in week *t*.
length	Length of vessel used for drift net fishing, in feet.
hp	Engine horsepower (in thousands) of vessel used for drift net fishing.
inclusive value	Inclusive value for area choice equation in week *t*.

permit, participating in other fisheries, and not fishing that week.[16] We estimate equation (1) as before, except that the subscript *j* now corresponds to the alternative activity instead of the alternative fishing area. The choices include all those fisheries that are legally available during the time period, for which the individual owns a boat with the appropriate gear if access is unrestricted, or for which the individual owns a limited entry permit. Specific alternative fisheries that were modeled include

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[16] Approximately 10% of setnet permit holders engaged in other fishing activities during the Cook Inlet salmon season as well as setnet fishing. An analysis of landings for this group when they are fishing their setnet permits shows that their operations are representative of the fishery as a whole.

halibut, other salmon fisheries, and all other fisheries. The *not fishing* alternative represents all productive nonfishing uses of people's time. The option not to fish in any Alaska commercial fishery is an additional alternative in each period.

We use the same data sources as for the drift fishery, as well as information on openings in alternative fisheries available to Cook Inlet setnet permit holders. We estimated similar equations to predict the catch and gross revenue for each fishing alternative. Table 5 shows the coefficients estimated for equation (1), with V_j given by equation (11), for setnetters' weekly choices of activities during the salmon fishing season for four consecutive years. Normalizing the coefficients on quantity in tables 3 and 5 by dividing by the scale factor, α, the results suggest lower incremental costs for the setnet fishery (about \$0.08 per pound), than for the drift fishery (about \$.85 per pound). The supply curves inferred from the coefficients suggest that restricting commercial openings would cause a greater loss of profits for setnet operations than for the drift fleet, but would also cause a bigger drop in participation among the drift fleet.

Welfare Effects of Management Changes

If managers increase the target escapement for the Kenai River, then they would most likely restrict the drift fleet by reducing inshore fishery hours in the area adjacent to the mouth of the Kenai River at the peak of the season, while leaving hours unchanged in the remaining areas.[17] This would affect revenue and costs expected in that area (area j), and change inclusive value for a single week—assumed to occur during the third week of July. The compensating variation for the change may be derived from integrating equation (4) and substituting equations (1), (2), (3), and (11), keeping in mind that the price of alternative j, p_j, equals the revenue (assumed fixed for the alternative).

Equation (9) yields the formula for compensating variation for the drift fishery for two scenarios, A and A', for open hours and catch that differ only for area j, where λ now equals $1 - \sigma$ (the coefficient on inclusive value in table 4) times the estimated coefficient on gross revenues (price) in table 3. While the formula for compensating variation is identical to that for the sport fishery, the formula for λ changes sign, indicating that the "price" (gross revenue) of the alternative, p_j, is now a benefit instead of a cost.[18]

Setnet operations in areas that are closed to fishing cannot change areas but may switch to other fisheries. The inclusive value summarizes information about the change in expected maximum earnings from all fishery alternatives. Integrating equation (4), substituting equations (1) and (11) and dropping the meaningless $1/(1 - \sigma)$ yields compensating variation for the setnet fishery (alternative s):

$$CV_s^A - CV_s^{A'} = \frac{1}{\lambda}\left[I(V_s^A) - I(V_s^{A'})\right] \tag{12}$$

where λ is now simply the coefficient α on gross revenue in table 5.

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[17] In years with low salmon runs, managers may have to close the entire Cook Inlet drift fishery to meet Kenai River escapement targets.

[18] The price of the alternative represents gross revenue, p_i, and not revenue less costs since dollar values are not observed for costs. The cost function can be inferred by dividing the coefficients by α, the coefficient on gross revenue.

Table 5

Equation for Fishery Choice, Setnet Permit Holders

Independent Variable	Coefficient Symbol	Estimated Coefficient	t-Statistic
revenue	α	1.059	12.08
notfish	$\alpha\delta_1$	0.284	6.89
halibut	$\alpha\delta_2$	–2.477	–22.85
salmon	$\alpha\delta_3$	0.314	5.91
other	$\alpha\delta_4$	–4.301	–17.95
salmonq	$\alpha\beta_1$	–0.00821	–14.95
salmqsq	$\alpha\beta_2$	0.000801	11.98
salmq3	$\alpha\beta_3$	–0.0000213	–9.96
otherq	$\alpha\beta_4$	0.282	11.03
otherqsq	$\alpha\beta_5$	–0.00339	–6.46
Log likelihood		–4,449.5	
Initial (slopes = 0)		–6,355.7	
Number of observations		3,949	

Definitions:

revenue	Expected gross value in billions of dollars landed in that fishery in week *t*.
notfish	Constant term for choice not to fish that week.
halibut	Constant term for choice to fish for halibut that week.
salmon	Constant term for participating in a salmon fishery other than Cook Inlet setnet that week.
other	Constant term for choice to fish for a species other than salmon or halibut that week.
salmonq	Expected pounds in billions of salmon harvested in any salmon fishery in week *t*.
salmqsq	Salmonq squared.
salmq3	Salmonq cubed.
otherq	Expected pounds in thousands of any nonsalmon fishery harvested in week *t*.
otherqsq	Otherq squared.

Measuring Net Benefits for Crew

Anthropologists (Pollnac and Poggie 1988; Gatewood and McCay 1990) as well as fishermen have argued that the enjoyment of fishing—the work, the working conditions, and the lifestyle—is an important reason fishermen sometimes choose fishing over other jobs where they could earn more. If job satisfaction is higher in fishing than in the next best alternative job, this difference in job satisfaction is part of the net economic value of the commercial fishery.

There can be both fixed and variable components to job satisfaction. Some satisfaction may derive from being a fishermen—the lifestyle, job location, and autonomy, for instance. Other satisfaction may be proportional to the hours worked: working outdoors, challenging the elements, the excitement, and the like. The hypothetical management changes we studied concerned the number, hours, and locations of commercial openings during a given week. Reductions in fishing time would reduce net income and hours of labor for permit holders and crew. In response, marginal operators might decide to pursue other work and not fish at all that week, or possibly even that season. This is a voluntary choice for the permit holder, reflecting high opportunity costs (good alternatives) to fishing. It implies a relatively small loss in net economic value (NEV) for the marginal permit holder. For the crew member, however, it is involuntary. For a crew member with poor alternatives, the loss in net economic value may be high.

Job Ranking Method

To estimate the NEV for workers, we must subtract the opportunity cost of work from the wages received. We can observe the wages paid to crew. The methodological challenge is to estimate the opportunity cost of fishing. One analytic solution is to assume a perfectly elastic supply of labor—*i.e.*, opportunity costs equal fishing wages. Another common solution is to assume that wage rates in other jobs measure the opportunity cost of fishing. This approach has been criticized for ignoring the nonmonetary benefits of fishing (Anderson 1980; Smith 1981; Gatewood and McCay 1990). If there are nonmonetary benefits to fishing, the wage rates in other jobs may overstate the opportunity cost of fishing work, thereby underestimating the net economic value.

The approach we use in this study is to ask crew members directly about their tradeoffs between fishing and other kinds of work that could substitute for the fishing crew job. Analyzing their responses that compare alternative jobs allows us to estimate the minimum earnings from Cook Inlet fishing that they would accept and still choose to fish. This measures the value of the work opportunities foregone, as valued by the fishermen themselves. Because we use individual measures of compensation and the opportunity cost of fishing, we do not need to make any assumptions about the labor market for Cook Inlet fishing crew.[19]

We again apply the assumptions of RUM and assume that the probability of choosing job j is a function of the relative utility of the job, V_j, and an independent random component, ε_j. V_j is modeled as a linear combination of seasonal job earnings (the "price" of that alternative, p_j) other income, y, that is invariant to the seasonal job choice, and a vector of nonwage benefits, working conditions, and other job quality characteristics, X_j:

$$V_j = \alpha(p_j + y) + \beta X_j. \tag{13}$$

The probability of choosing job j is then given by the familiar equation (1).

Although a few crew work only a day or two at the peak of the run, many work up to twenty weeks. Permit holders typically hire crew for the season. In addition, many crew are nonlocal residents who travel to the area and expect to stay for the season. Therefore, the choice horizon for equation (1) is the season.

Data

The data on alternative jobs come primarily from a survey of Cook Inlet crew members. We asked crew survey respondents eighteen years and older a series of questions about other jobs they held in past summers and the type of job they would look for if they were to look for summer work in the future. We asked about expected earnings, benefits, risks, job security, and various kinds of working conditions for each of these jobs. Then we asked respondents to rank the jobs, including commercial fishing, from the most preferred to the least preferred. We then asked them to rank the jobs again, given a 20% pay increase in the top-ranked alternative job or a 10% decrease in income from the Cook Inlet fishery. We also asked a series of questions about what job characteristics generally are the most important and least important to them in choosing jobs. The

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[19] A more complete analysis would have included leisure as an alternative.

Table 6

Crew Job Ranking Equation

Variable		Coeff.	t-Statistic	Variable Mean	Std. Dev.	Mean * Coeff.	Std. Dev. * Coeff.
earn	α	0.0788	4.06	4.450	4.586	0.350	0.361
setci	$-\alpha\beta_1$	1.872	2.04	0.288	0.453	0.539	0.849
weekset	$-\alpha\beta_2$	−0.170	−1.92	2.408	4.177	−0.409	−0.709
hpwset	$-\alpha\beta_3$	0.0280	1.70	15.580	26.570	0.436	0.743
driftci	$-\alpha\beta_4$	0.551	1.28	0.141	0.348	0.078	0.192
hpwdrft	$-\alpha\beta_5$	0.0163	2.36	8.461	24.390	0.138	0.398
certain	$-\alpha\beta_6$	1.149	6.00	0.276	0.447	0.317	0.514
office_s	$-\alpha\beta_7$	1.139	3.44	0.008	0.272	0.092	0.310
Log-likelihood			−152.69				
Restricted (slopes = 0) log-l.			−201.45				
Chi-squared (8)			97.522				

Definitions:

earn	Earnings for the season or duration of the job; if the job is year-round, this is earnings for a period comparable to Cook Inlet fishing.
setci	1 indicating a Cook Inlet setnet job; 0 otherwise.
weekset	The number of weeks from the start of the setnet fishing job to the end.
hpwset	The number of hours per week worked setnetting during the season.
driftci	1 indicating a Cook Inlet drift net job; 0 otherwise.
hpwdrft	The number of hours per week worked setnetting during the season.
certain	1 if the *ex ante* expected earnings for the job were known with some certainty; 0 if the expected earnings were uncertain.
office_s	1 indicating an office job, for those who expressed a strong preference for working outdoors.

finished data set included observations on 218 job alternatives for 100 crew members.[20]

We estimated equation (1), with V_j given by equation (13), using a rank order logit (Beggs, Cardell, and Hausman 1981). The equation results appear in table 6. The earnings coefficient estimates how important money is relative to nonmonetary factors in explaining job choices. The coefficient here is positive and statistically significant. Yet earnings are less important in explaining job preferences than the Cook Inlet setnet dummy or either of the two measures of setnet fishing time. The set dummy and hours worked per week have positive coefficients, while weeks worked has a negative coefficient. These results indicate that there is a large fixed value to setnet fishing, as well as significant benefit to the hours per week spent working and significant cost to the total weeks worked.

The drift fishery shows a different pattern: the hours worked per week is the only significant drift variable, and it has relatively weak explanatory power. (In the weighted data set, setnetters outnumber drifters two to one, so relatively fewer drift observations contribute to the equation estimate.) Other variables found to be significant were the certainty of earnings and the work environment. The positive coef-

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[20] A sample of Cook Inlet drift and east-side setnet crew members were interviewed by telephone in fall 1994. The survey excluded crew members under the age of eighteen—about 15% of the approximately 2,000 crew members in the fishery. Crew who held limited Cook Inlet entry permits were also excluded because they are included in the permit holder analysis. The analysis also does not include crew who were not working as Cook Inlet crew but might value the opportunity to do so in the future. Since the changes we model are marginal changes in hours or weeks worked, the impact on this group is likely to be negligible. This hypothetical exercise in job choice is subject to many of the same controversies as contingent valuation.

ficient on office_s, indicating both a strong preference for working outdoors and preference for an office job, might be interpreted as a desire for complementarity.

Welfare Effects of Management Changes

Crew members' compensating variation from Cook Inlet fishing jobs may be estimated from the job ranking model in the same manner as other discrete choice models. Because we model only a single-stage decision structure for crew members, integration of equation (4) produces an identical equation as shown in equation (12) for setnet permit holders. We merely substitute equation (13) for V_j in place of equation (11). We predict changes in fishing hours or weeks for crew from simulated changes in participation predicted by the estimated equations for drift and setnet permit holders.

Comparison of Net Benefits for Sport and Commercial Fisheries

To compare changes in net benefits for sport and commercial fisheries under different sets of assumptions, we developed a number of scenarios with varying run sizes, prices, and management strategies. Assumptions for ex-vessel sockeye prices ranged from $1.00 to $1.75 per pound. We modeled how ADFG fishery managers would regulate the commercial and sport fisheries to meet three amended escapement targets under three run size scenarios: fewer than 2 million, 2–5 million, and more than 5 million sockeye returning to the Kenai River system.

Table 7 summarizes our results for the three user groups under a scenario that allocates an additional 200,000 sockeye past the Kenai River sonar counter, moving from a target of escapement of 400,000–700,000 to a target of 600,000–900,000 fish. Figures in the table assume a medium size run (3.5 million sockeye) and the 1994 season average price ($1.43). Management biologists estimate that the target reallocation of 200,000 more sockeye would entail two or three fewer emergency setnet and driftnet openings in the corridor along the beach just below the mouth of the Kenai River during the latter part of July. Because of the incidental commercial catch of other salmon species and salmon bound for other rivers, as well as the sport harvest in the River below the sonar counter, biologists estimate commercial fishermen would give up about 245,000 sockeye and 11,600 other salmon to get 200,000 more sockeye past the sonar. We project that this would cause a net loss of compensating variation to setnet operations of around one million dollars, or $0.98 per pound. The drift fleet would suffer a net loss of about $300,000, or $0.71 per pound. The resident share of these losses would be about $934,000 and $222,000 respectively.[21]

Crew members eighteen and over would lose an estimated $963,000 in compensating variation. The resident share is about $598,000. Half of this figure consists of earnings, and half is a nonmarket loss of work satisfaction. The average losses are $705 for resident drift crew members and $1,414 for resident setnet crew.

For this scenario we estimate that southcentral Alaska sport anglers would make about 4,000 additional trips to Kenai River sites during July, with a net increase in total fishing trips of about 650. The net economic value of the sport fishery to resident angling households would increase by a total of about $1.3 million. This repre-

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[21] This analysis focused on resident losses because decision makers used a state accounting frame. The sport fish results also include only benefits to residents.

Table 7

Changes in Net Economic Value for Sport and Commercial Fishers From Increasing the Sockeye Sonar Count by 200,000

Sport Anglers

	Change in Net Value Per Angler Household (a)	Number of Resident Angler Households (b)	Change in Net Value to Resident Anglers (c) = (a) × (b)
	$22.17	61,000	$1,345,291

Commercial Permit Holders

	Change in Net Value Per Permit (a)	Total Number of Permits (b)	Resident Percent of Landings (c)	Change in Net Value to Resident Permit Holders (d) = (a) × (b) × (c)
Drift gillnet	$(451)	583	0.73	–$191,187
Setnet	(1,409)	745	0.89	–932,243
Total				–$1,123,430

Commercial Crew Members

	Change in Net Value Per Resident Crew Member (a)	Number of Resident Crew Members (b)	Change in Net Value to Resident Crew Members (c) = (a) × (b)
Drift gillnet	$(705)	401	–$283,199
Setnet	$(1,414)	594	–315,295
Total			–$598,494
Commercial Permit Holders and Crew			
Total			–$1,721,924

Note: Assuming a run size of 3.5 million and a price of $1.43 per pound.

sents about $22 per household for 61,000 southcentral households with sport anglers in 1993. The increase in total net value calculates to only $6.73 per fish reallocated (state biologists estimate that less than one-fourth of the additional sockeye would be harvested by sport anglers).

Confidence intervals cannot be calculated analytically for discrete choice models. For complex models such as these, numerical analysis was beyond the reach of our project resources. We did, however, do sensitivity analysis on the travel cost estimate of angler net economic value. We focused on the estimated confidence interval for the coefficient on our most important variable—the sonar count. The 5% upper and lower bound estimates for the sonar coefficient generated net value estimates that ranged from –43% to +68% of the most likely value for this scenario. The difference between projected losses by commercial fishermen and the projected gains by sport anglers in this scenario is relatively small compared to the imprecision of the estimates, despite the strength of the statistical results.

Table 7 compares estimated changes in net economic value for the commercial and sport fisheries for one of the ten scenarios modeled. Other scenarios explored different assumptions regarding management, run size, and price. High runs were not modeled because in high run years there is a surplus of fish and the reallocation target would not affect management. Low run, and high and low price assumptions, have very little effect on the sport side, but do affect commercial management and fishing effort. Low run assumptions for Kenai River sockeye dramatically affect commercial net value because managers would more severely restrict commercial fishing to put the same target number of fish in the river. The losses of value from incidental catch would be magnified as other stocks make up a greater proportion of total commercial harvest when Kenai River sockeye runs are low. If low runs were combined with low prices, fewer operators would be fishing, mitigating losses due to the proposed management changes. High prices increase commercial losses by amplifying the value of the harvest foregone.

Conclusions

The empirical findings of this study cannot be generalized to other fisheries. The particulars of geography, biology, technology, and management largely drive the net benefit estimates. The sequential relationship and relative efficiency of the commercial and sport fisheries plays a key role. If sport anglers harvest one out of five additional fish that pass the commercial nets, the value of a sport-harvested fish must be more than five times the value of a commercially-harvested fish for a reallocation to increase net economic value. The focus in this study on resident values—excluding the nonresident anglers who comprise half of the fishing effort on the Kenai River—also limits wider application.

It is the methodology that has broad application. A general model of individual decision making, built with micro data, has great flexibility to predict behavior and estimate net benefits under a variety of scenarios and policy alternatives. In contrast, contingent valuation studies apply only to the few alternatives that were precisely specified in the survey. Furthermore, a model built from observed choices, such as the travel cost and landings models, is less subject to respondent bias than a model built from hypothetical choices. In contrast to an accounting model of net profits that requires good data on marginal costs, the observed choices model estimates producers' profits and marginal costs using only readily observed data on activities and revenues. A discrete choice model also incorporates nonmarket benefits and opportunity costs, such as the value of time, job satisfaction, or the quality of a recreational experience. Comparably valuing market and nonmarket benefits and costs is crucial when comparing sport and commercial fishing.

Three main limitations of discrete choice models are the sensitivity of results to model structure, the difficulty in assessing model accuracy, and large microdata requirements.

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