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ABSTRACT: Commercial, sport, personal use, and subsistence fishers share the salmon harvest on the Copper River, Alaska. The allocation of salmon among these user groups is a contentious and recurring issue. Economic analyses, along with biological, legal, social, and cultural considerations, have the potential to help policy makers appreciate the consequences of alternative allocations. The zonal travel cost method is used in this study to estimate the net economic value (consumer surplus) of the Copper River basin personal use and subsistence fisheries. The nature of the fishery and the data set are especially well suited for this purpose.

INTRODUCTION

Copper River basin salmon are important to the livelihood and lifestyle of many Alaskans. Returning salmon in excess of escapement objectives are available for commercial, subsistence and personal use, and sport harvest. The annual harvest of chinook *Oncorhynchus tshawytscha*, sockeye *O. nerka*, and coho *O. kisutch* salmon averages 1.6 million fish. Responsibility for allocating catch shares among competing user groups resides in the Alaska Board of Fisheries and is among the most contentious and perennial management issues faced by the Board.

The commercial fishery is comprised of 505 limited entry permit holders who fish off the river's mouth near Cordova, Alaska, and focus on the June–July mixed run of sockeye and chinook salmon (ADF&G 1996). Resident and nonresident fishers can hold limited entry permits. The commercial fishery generates about $8 million gross ex-revenues per year.

The sport fishery targets chinook salmon in the Copper River's clear tributaries, most notably the Gulkana and Klutina Rivers. Approximately 30,000 anglers participated in the sport fishery during 1996 and harvested approximately 3% of the chinook salmon catch (ADF&G 1996). The sport fishery is open to resident and nonresident license holders, subject to season, geographic, gear, and bag restrictions.

The personal use and subsistence fisheries allow participants to harvest fish for personal consumption and traditional exchanges. Changes in historical subsistence use patterns are described in Fall and Stratton (1984). Depending on run strength and harvest level, these fisheries are open from June through September and are concentrated along a 10-mile stretch of the Copper River near Chitina, Alaska. During the first 12 weeks of the season, sockeye salmon comprise 97% of the harvest, and chinook salmon comprise the remaining 3%. During the last 5 weeks of the season, the harvest is typically 63% sockeye salmon and 37% coho salmon. Participation in the personal use and subsistence fisheries is restricted to Alaska residents who possess a resident sportfishing license ($15) and pay an annual access fee ($10). The access fee is the result of an agreement between the Ahtna and Chitina Native Corporations and the state, which allows personal use and subsistence fishers limited trespass rights on certain native land holdings. The State of Alaska transfers all access fee receipts to the Ahtna and Chitina corporations.

Rules governing eligibility for participation in the personal use and subsistence fisheries have changed

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Table 1. Statistical summary of variables included in the ADF&G Copper River basin fishery database.

Variable	Median	Mean	SD	Minimum	Maximum
Family size per permit	3	2.984	1.624	0	72
Number of trips per permit	1	1.5	0.869	1	5
Number of sockeye salmon per trip	6	11.756	17.446	0	493
Number of coho salmon per trip	0	0.465	1.281	0	85
Number of chinook salmon per trip	0	0.229	1.985	0	99

over time and will continue to evolve. Before 1989, subsistence-permit eligibility was restricted to residents of certain rural communities, although all state residents were eligible for personal use permits. Following the overturn of state laws that based subsistence eligibility on residency in rural communities, every Alaska resident became eligible for a subsistence permit. Subsequent litigation, and in particular, the expansion of federal authority pursuant to the Ninth Circuit Court's decision in *Alaska v. Babbitt* (*Katie John*) (54 F. 3rd 549 [9th Cir. 1995]), and the October 1, 1999 federal assumption of subsistence fisheries management authority under the Alaska Native Claims Settlement Act (43 U.S.C. 33), can be expected to stimulate additional evolution of eligibility criteria for participation in the personal use and subsistence fisheries.

Personal use and subsistence permits are issued to individuals or families for fish wheels or dip nets. Neither fishery is restricted to one gear type; however, most subsistence fishers use fish wheels, and most personal use fishers use dip nets. Personal use season bag limits vary according to run strength, and individuals and families usually have been allocated 15 and 30 fish, respectively. These bag limits include a maximum of 5 chinook salmon. Although subsistence fishers may request larger bag limits, the standard bag limit is 30 fish per individual, 60 per 2-member family, and 10 more salmon for every additional family member. Approximately 7,000 personal use and 800 subsistence permits are issued each year, 15% to individuals and 85% to families. Subsistence and personal use fishers harvested 2% and 4% of the 1996 Copper River stock salmon harvest, respectively (ADF&G 1996).

Although there have been several economic analyses of Alaska's commercial salmon fishery (e.g., Boyce et al. 1993, Herrmann and Greenberg 1994) and the sport fishery (Layman et al. 1996), there are no comparable economic studies of the personal use and subsistence fisheries. We attempt to address this lack by developing estimates of the consumer surplus per household for permit holders in the personal use and subsistence fisheries.

METHODS

The Alaska Department of Fish and Game (ADF&G) maintains a time series-panel database constructed from information submitted on the personal use and subsistence permit applications and reports. The data collection instrument is a single-page 3-part form that includes the permit application, the permit, and a fish transportation permit. Personal use and subsistence fishers are required to record, on their harvest and transportation permits, the date of their trip(s) as well as the number and species of fish caught. Individuals who neglect to return their permit at the end of each trip may be denied a permit in the following year. Individuals in possession of more fish than the number recorded on their harvest and transportation permits are subject to prosecution. In addition to reported catch, each permit identifies the fisher's home address and household size for family permits. The database includes records for each subsistence and personal use trip completed between 1988 and 1998. See Table 1 for a descriptive summary of these variables.

The model selected for data analysis was a zonal travel cost model (TCM) adjusted for unequal zones following Strong (1983). Zonal TCM was chosen for 3 reasons. First, the existing data included all information needed for estimation of a zonal TCM, whereas the information requirements for other valuation methods would have necessitated an expensive survey. Second, the ADF&G database does not include observations on individual or household income. Third, many participants in the personal use fishery, and most participants in the subsistence fishery, reside in communities with mixed economies. They generally have a limited frame of reference for valuing food items that are usually acquired through individual or group harvest activity or through gifting or exchange for other nonmarketed foods and products. Consequently, many of the fishery participants would have little basis for responding to a contingent valuation survey. Implementation of zonal TCM presupposes that the observations can be aggregated into visits from mutually exclusive homogenous zones. Consequently, the zones must be constructed such that participants share simi-

Table 2. Summary statistics for travel distances and demographic variables.

Variable	Mean	SD	Minimum	Maximum
Distance to Chitina (m)	380.63	306.18	0.50	1,494
Travel time to Chitina (h)	10.70	10.91	0.02	43.20
Median household income	$25,045	$3,945	$16,734	$35,413
Community population	5,586	12,984	25	75,819
Households per community	1,346	2,199	1	8,603
Annual unemployment rate	0.18	0.14	0	1
Median age	29.87	1.66	26.4	34.20
Percent of population that is Alaska Native	0.16	0.19	0.05	0.73
Percent of population that is male	0.59	0.13	0.51	0.90
Percent of population on public assistance	0.10	0.09	0.00	0.37

lar income and demographic characteristics as well as similar travel costs.

Zones

Participants in the Chitina personal use and subsistence fishery travel from throughout the state with one-way distances ranging from 0.5 to 1,494 miles. Most participants live in Copper River basin communities (Chitina, Glennallen, Gulkana, and Copper Center), South Central communities (Anchorage, Eagle River, Wasilla, and Palmer), the Kenai Peninsula region (Homer, Seward, Soldotna, and Kenai), and the Interior (Cantwell, Delta Junction, Fairbanks, North Pole, Nenana, and Healy). A few individuals travel from the Southeast region (Juneau, Ketchikan, Sitka, and Wrangell), and the Arctic region (Kotzebue, Nome, Barrow, and Deadhorse). The range of variability in travel distances and demographic characteristics is summarized in Table 2.

The most direct route from the center of each zip code area in each community was used to determine the distance traveled. Trips by residents of communities that are not road accessible (less than 1% of the 1980–1998 trips) were omitted because participants from these communities incur substantial air-travel costs, and these trips are probably multipurpose.

The 1990 census (U.S. Department of Commerce 1991) provides median household income by zip code for 1990. This income is reported as a before-tax income; hence, all income was adjusted by the average Alaskan tax liability, by income bracket. Because there is no other consistent source of information on median household income data for Alaska, this research focuses only on the 1990 permit trip data.

The distance and travel route from the community to the fishery, and the 1990 median household income were used to identify 75 zip code zones. One-way travel distance for communities within zones differed by no more than 40 miles. Within-zone variation in median incomes differed by 14% or less.

Variable Construction

Although the permit database provided much of the information needed to implement the zonal TCM, visitation rate and travel cost were latent and were constructed from secondary sources. The visitation rate VR_i was defined as the ratio of trips to households in zone *i*. The travel cost TC_i was defined as the sum of site fees, the travel distance cost (the product of distance and cost per mile), and time cost (the product of travel time and the opportunity cost of time) from zone *i*. Median household income was used as a proxy for the wage rate.

We chose to define visitation rates by households because most permits are issued on a household basis, and the database does not provide the number of individuals who fished the permit per trip. Because Chitina is near the end of a road that terminates in the Wrangell Mountains and is not on any direct route between major population centers, we assumed household trips to fish the Copper River were single purpose, and only one permit was fished for each trip to Chitina. This assumption ignored the possibility that some participants might have carpooled on some trips and created a downward bias in the visitation rate estimates. Because participants are instructed to report their catches per trip on a single line on the permit, we assumed each date with recorded catches represented a separate trip. However, some individuals may have mistakenly recorded their daily catches on separate lines. Consequently, some multi-day trips may have been misconstrued as multiple trips, leading to an upward bias in the visitation rate estimates.

It was not possible to obtain separate estimates of consumer surplus for subsistence and personal use participants in the Chitina fishery. The zonal TCM

Table 3. Estimated travel costs resulting from varying the percentage of wage rate in the models.

Time Cost	Cost Per Mile	Mean Travel Cost	SD	Minimum	Maximum
30% of wage rate	$0.31	$309.76	$252.38	$5.23	$1,121.06
60% of wage rate	$0.31	$384.31	$320.38	$5.39	$1,399.11

requires estimates of the visitation rate for each zone. Although the number of subsistence and personal use fishers from each zone could be identified, we could not identify how the ratio would change in response to a cost increase, or how many nonparticipants attracted by a cost decrease would enter the subsistence fishery or the personal use fishery.

Travel Costs

The travel distance cost was defined as the product of the round trip distance from each zone to Chitina and the cost per mile. We used the State of Alaska reimbursement rate of $0.31 per mile, for employee use of a personal vehicle for official business, as a proxy for the total cost of vehicle operation.

Previous studies have recognized the opportunity cost of time spent traveling to a site should be included to estimate the demand for visits (Knetsch 1963, Cesario and Knetsch 1970, Cesario 1976, McConnell and Strand 1981). However, the appropriate opportunity cost of time depends on the alternative uses of the time and on the nature of constraints on individual choice. With a higher opportunity cost of time, the estimated demand curve is less elastic and the total value of the site is higher. Unfortunately, it is difficult to identify the opportunity cost of time. Most studies have assumed the opportunity cost of time is between 25% and 60% of the wage rate (Smith and Kaoru 1990, Shaw 1992). Our research used 30% and 60% of the wage rate to allow direct comparisons with the Copper River sport fishery study by Layman et al. (1996). Annual median income was divided by 2,000 h/year to approximate the average hourly wage rate. The cost related to travel time was specified as the product of the round trip time at 55 mph along the minimum distance route from each zone to Chitina and 30% or 60% of the average wage rate of residents in that zone.

The $10 annual access fee was converted into a zone-specific per-trip cost by dividing the access fee by the average number of trips per permit from that zone. The range of variability in the estimated travel costs is reported in Table 3.

Substitute Sites

Failure to consider substitute sites biases coefficient estimates and inflates the value of the estimated consumer surplus per visit (Smith and Kaoru 1990). Although there are other personal use and subsistence fisheries, the only close substitute for the Copper River fishery is the Upper Cook Inlet personal use fishery near the mouth of the Kenai River. The Kenai River personal use fishery is a road-accessible dip net fishery with bag limits similar to the Chitina fisheries and is open from July 10 to August 5. Travel costs to the Kenai River dip net area were based on the same assumptions applied to the Copper River fishery.

Demographic Variables

The inclusion of variables related to demographic characteristics may reduce the variance of model residuals and lead to more robust estimates of consumer sur-

Table 4. Coefficients and *t*-statistics generated by the restricted model.

	Time Cost at 30% of Wage Rate		Time Cost at 60% of Wage Rate	
Model	Coefficient	*t*-statistic	Coefficient	*t*-statistic
Intercept	-3.874	-5.241*	-3.840	-5.367*
TC	-0.007	-2.976*	-0.006	-3.246*
KTC	0.005	2.314*	0.004	2.603*
PublicAssistance	-11.412	-2.205*	-10.878	-2.145*
Unemployed	8.799	2.100*	8.881	2.168*
Rural	0.361	0.467	0.384	0.510
Subsistence	0.014	1.535	0.012	1.293
Adjusted R^2		0.382		0.403
RMSE		1.949		1.915
df		40		40

* significant at the 95% confidence level

Table 5. Consumer surplus estimates.

Time Cost	Total Consumer Surplus	Consumer Surplus Per Household Permit (n = 5,979 permits)	Consumer Surplus Per Trip (n = 8,456 trips)
30% of wage rate	$430,655	$72.03	$50.93
60% of wage rate	$481,012	$80.45	$56.88

plus (Bockstael and Strand 1987). In addition to travel costs, we considered the percentage of males, the percentage of Alaska Natives, and the median age in each zone. Unemployment rates and the percentage of residents receiving public assistance within the communities of each zone may also explain differences in visitation rates. Due to the federal guidelines for subsistence, rural designation is of primary importance to the fishery and was included as an explanatory variable. Annual unemployment rates, the percentage of communities with rural designation, and the percentage of community residents receiving public assistance were obtained by zip code from the 1990 census. To identify influences of permit-type composition (i.e., personal use and subsistence) across zones on visitation rate, a variable representing the percentage of subsistence trips for each zone was established from the database.

RESULTS

The number of subsistence permits fished per zone was inversely related to travel distance. The 10 zones within 200 miles of Chitina accounted for 91% of all subsistence trips taken in 1990. In 7 of these zones, more than 90% of all trips were subsistence trips. Gakona, Mentasa, Chickaloon, and Northway were 100% subsistence. In contrast, participation from other regions (Sutton, Delta Junction, Houston, Wasilla, Anchorage, Talkeetna, North Pole, Chicken, Healy, Anderson, Nenana, Seward, and the Kenai Peninsula) was strictly personal use.

The visitation rate (VR_i) is the number of trips from a zone divided by the total number of households in that zone and can be represented as

$$VR_i = f(TC_i, KTC_i, Rural_i, PublicAssistance_i, Unemployed_i, Native_i, Gender_i, Age_i, Subsistence_i). \quad (1)$$

The travel costs incurred during trips from zone i to Chitina or the substitute site are TC_i and KTC_i, respectively. *Native* and *Rural* are the percentage of Alaska Natives and the percentage of residents that meet federal subsistence eligibility criteria. *Unemployed* and *PublicAssistance* are the annual unemployment rate and the percentage of the population on public assistance in each zone. *Gender* is the percentage of males. *Age* is the median age of residents by zone, and *Subsistence* is the percentage of subsistence permit trips taken from zone i.

The functional form of the visitation rate equation is unknown. Previous applications of zonal TCM have adopted linear, semi-log, double-log, and log-linear specifications. We adopted a semi-log specification because the linear specification led to significant heteroskedasticity in the residuals, and because it is the preferred specification for zonal TCM (Strong 1983).

$$ln(VR_i) = b_0 + b_1 TC_i + b_2 KTC_i + b_3 Rural_i + b_4 PublicAssistance_i + b_5 Unemployed_i + b_6 Native_i + b_7 Gender_i + b_8 Age_i + b_9 Subsistence_i . \quad (1')$$

The coefficients in equation (1') were estimated using the 47 non-zero visitation-rate observations for *TC* and *KTC*. The sign (positive or negative) of each estimated coefficient conformed with theoretical expectations. All coefficients except those for *Rural*, *Subsistence*, *Native*, *Gender*, and *Age* were statistically significant at $a = 0.05$. Thus *Native*, *Gender*, and *Age* were dropped, and the model was reestimated using 30% and 60% of the wage rate for the opportunity cost of time. *Rural* and *Subsistence* were retained because these variables were important to the personal use and subsistence permitting system. The estimated coefficients, with the *t*-statistics in parentheses, are given in Table 4. As expected, the estimated models suggested site visitation rates decline as a function of increased travel costs, and increase as costs of travel to substitute sites increase. Rural zones with high unemployment and high percentages of subsistence users had higher visitation rates. However, the coefficients for *Rural* and *Subsistence* were not statistically significant.

Consumer Surplus Estimates

The area under the demand curve is a measure of the value of the site or activity. Consumer surplus would

Table 6. Krinsky-Robb simulation consumer surplus (CS) confidence interval estimates.

Time Cost	K-R Median CS	95% CI Lower Bound	95% CI Upper Bound
30% of wage rate	$516,851	$286,553	$1,106,294
60% of wage rate	$578,426	$323,003	$1,170,749

reflect the average benefit per person if a per capita travel cost was established; however, the travel costs used in this research is a household permit trip cost. Therefore, consumer surplus is the value of the use of household permits. Estimating different models for individual households and family households would have been more appropriate, but the available income data do not provide income by family households or households of one. Hence, consumer surplus divided by total number of household permits yields average benefit per household.

Because the demand curve is estimated from a statistical model that associates random errors with estimated parameters, consumer surplus estimated by integrating the area under the demand curve is a random variable with uncertain properties (Adamowicz et al. 1989). To address this problem, Smith (1990) suggests it is preferable to statistically estimate welfare measures directly rather than derive them from estimates of demand function parameters.

Models that valued the opportunity cost of time at 30% and 60% of the wage rate were used to derive consumer surplus estimates because they span the range of likely parameter specifications. Following Smith (1990), consumer surplus (CS) was estimated as

$$CS = \sum_{i=1}^{75} \left\{ \frac{Households_i}{\hat{b}_1} \exp^{x} \left[\exp\left(\hat{b}_1 P^*\right) - \exp\left(\hat{b}_1 TC_i\right) \right] \right\}, \quad (2)$$

where $Households_i$ is the total number of households in zone i, and P^* is the choke price estimated from each demand equation, and

$$x = \hat{b}_0 + \hat{b}_2(KTC_i) + \hat{b}_3\left(Rural_i\right) + \hat{b}_4\left(PublicAssistance_i\right) + \hat{b}_5\left(Unemployed_i\right) + \hat{b}_6\left(Subsistence_i\right).$$

The total consumer surplus estimates ranged from $430,655 to $481,012 and represented the value above and beyond the price (travel cost) individuals paid to participate in the fisheries (Table 5). Dividing consumer surplus by the number of 1990 permits (5,979) provided the average value of a personal use and subsistence permit to a household. Values per permit for a household ranged from $72.03 to $80.45.

Confidence intervals were estimated using the simulation method (Krinsky and Robb 1986). The simulation generated parameters with the same mean and variance as the estimated parameters. These generated parameters were used to compute consumer surplus. We generated 2,000 sets of parameters and computed 2,000 consumer surplus estimates. These estimates provided the 95% confidence intervals presented in Table 6. At the simulated 95% confidence level, the lower bound of consumer surplus ranged from $286,553 to $323,003, and the upper bound ranged from $1,106,294 to $1,170,749 depending on the value for the opportunity cost of time.

CONCLUSIONS

Nearly 6,000 households participated in the Copper River personal use and subsistence fisheries in 1990. Estimates of consumer surplus ranged from $50.93 to $56.88 per trip depending on the assumed opportunity cost of time. The point estimates are nearly twice as large as those reported by Layman et al. (1996) for the Gulkana River sport fishery. They report consumer surplus estimates for sport fishing on the Gulkana River of $26.05 to $32.35 per trip for models with the opportunity cost of time at 30% and 60% of the wage rate, respectively. After adjusting for inflation between 1992 and 1996, the estimates of consumer surplus are $28.55 and $35.46 per sport fishing trip. The estimates of consumer surplus for personal use and subsistence trips are also within the lower-bound estimate of the replacement cost of the personal use and subsistence catches. An upper-bound estimate of the foregone gross exvessel revenue associated with an average subsistence or personal use trip is $98.09.[1] The opportunity cost of personal use and subsistence harvests to commercial fishers would be the difference between this value and the incremental cost of catching a fish.

One objective of this analysis was to demonstrate that economic measures of recreational benefits can

[1] ($1.60/lb)(24 lb/chinook)(0.229 chinook/trip) + ($1.30/lb)(5.7 lb/sockeye)(11.756 sockeye/trip) + ($0.50/lb)(9.4 lb/coho)(0.465 coho/trip)

be derived from data routinely collected by management agencies. Although we were successful in achieving this objective, we were unable to fully exploit this otherwise rich data because of the lack of household income information. This constrained our analysis to a zonal rather than an individual-based travel cost model and prevented us from examining changes in participation over time because the 1990 census was the only available source of household income estimates at the zip code level. This limitation could be alleviated by inclusion of a question about household income on the permit application.

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