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ARTICLE

Economic Value of Angling on the Colorado River at Lees Ferry: Using Secondary Data to Estimate the Influence of Seasonality

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Abstract
Glen Canyon Dam (GCD) on the Colorado River in northern Arizona provides water storage, flood control, and power system benefits to approximately 40 million people who rely on water and energy resources in the Colorado River basin. Downstream resources (e.g., angling, whitewater floating) in Glen Canyon National Recreation Area (GCNRA) and Grand Canyon National Park are impacted by the operation of GCD. The GCD Adaptive Management Program was established in 1997 to monitor and research the effects of dam operations on the downstream environment. We utilized secondary survey data and an individual observation travel cost model to estimate the net economic benefit of angling in GCNRA for each season and each type of angler. As expected, the demand for angling decreased with increasing travel cost; the annual value of angling at Lees Ferry totaled US$2.7 million at 2014 visitation levels. Demand for angling was also affected by season, with per-trip values of $210 in the summer, $237 in the spring, $261 in the fall, and $399 in the winter. This information provides insight into the ways in which anglers are potentially impacted by seasonal GCD operations and adaptive management experiments aimed at improving downstream resource conditions.

Glen Canyon Dam (GCD) on the Colorado River in northern Arizona was constructed in 1963 for the primary purposes of water storage, flood control, and hydroelectric power generation (Bureau of Reclamation 1995). The operation of GCD for these purposes affects downstream resources in Glen Canyon National Recreation Area (GCNRA) and Grand Canyon National Park (GCNP). Such resources include recreation, such as angling and whitewater floating; ecosystem services; and historic and cultural sites. Attempts to balance GCD operations and downstream resource conditions eventually led to the Grand Canyon Protection Act (GCPA) of 1992 and the modification of GCD operations to achieve less diurnal variation in Colorado River flows (Bureau of Reclamation 1996). Management of downstream resources that are impacted by the operation of GCD is an ongoing resource management priority (U.S. Department of the Interior 2015).

After the construction of GCD, nonnative Rainbow Trout *Oncorhynchus mykiss* were introduced downstream of the dam, thereby creating a coldwater trout fishery in an

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approximately 24-km, clear-water reach of the GCNRA (Rogowski et al. 2014). The fishery offers Rainbow Trout angling opportunities, attracting anglers from throughout North America. Dam operations and the angling experience have changed since the early 1990s, and use has varied widely over the past several decades—from 5,000 to 25,000 anglers/year (Loomis et al. 2005; Rogowski et al. 2015). Diurnal and seasonal variation in Colorado River flows and implementation of controlled, experimental high-flow releases from the dam, known as high-flow experiments (HFEs), have significantly altered Rainbow Trout recruitment (McKinney et al. 2001; Korman and Campana 2009; Korman et al. 2011a, 2011b, 2012) and the food base (Cross et al. 2011, 2013). The HFEs generate in-channel transport of Colorado River tributary sand inputs to build sandbars downriver. The diurnal and seasonal variation in Colorado River flows and the periodic HFEs may enhance or diminish the recreational experiences in GCNRA and GCNP. The GCPA stipulates a continuation of monitoring and research through an adaptive management program to determine the effects of GCD operation on downstream resources, including recreation (GCPA section 1805b).

The trout fishery in GCNRA (also known as Lees Ferry) is a significant downstream recreational resource. The biological and economic effects from the operation of GCD constitute important information when balancing resource management goals in GCNRA and GCNP. Several researchers have estimated recreational angling demand with revealed-preference or stated-preference survey methods to inform resource management (e.g., Reilley 2011; Loomis and Ng 2012; Hutt et al. 2013; Blaine et al. 2015). At Lees Ferry, Richards and Wood (1985) used an on-site survey and a mail survey to estimate a travel cost model for identifying trophy and nontrophy angler values so as to better understand angler preferences. In addition, Bishop et al. (1987) used a contingent valuation method survey to estimate angler values at different levels of Colorado River flow, informing on the impacts of dam operation. However, Colorado River flows—as well as the fishery quality, angling regulations, and angling practices and participation —have changed significantly since those studies were conducted.

Researchers have developed travel cost models that utilize on-site secondary data to estimate recreational demand (Bowker et al. 2009; Heberling and Templeton 2009; Benson et al. 2013; Neher et al. 2013). On-site secondary data allow for the use of existing information to estimate demand for nonmarket recreational activities. Heberling and Templeton (2009) modeled the economic value of visitation to Great Sand Dunes National Park and Preserve by first implementing the use of Visitor Service Project data. Furthering the methods used to address challenges associated with secondary data, Bowker et al. (2009) estimated recreation values on U.S. Forest Service land, whereas Neher et al. (2013) estimated recreation values for a system of national park sites. Benson et al. (2013) continued to broaden the application of secondary data in revealed-preference research, estimating how groups of specific visitors valued activities within Yellowstone National Park.

The objectives of the present study were to estimate angler demand and subsequent net economic benefits (i.e., consumer surplus) of the trout fishery in Lees Ferry for each type of angler and each season. Identification of the seasonal variation in angler benefits allows natural resource management agencies to better understand how anglers are impacted by the seasonal aspects of hydropower generation, ecosystem dynamics, and other recreational uses in GCNRA and GCNP. Estimating the value of the Lees Ferry trout fishery can also inform (1) the allocation of limited resources when managing for uncertain future hydrology and ecosystem conditions in the Colorado River; and (2) improvements in the timing of management intervention (e.g., invasive species removal) or adaptive management experiments to protect or improve resources in GCNRA and GCNP. Secondary data were generated through annual creel surveys conducted by the Arizona Game and Fish Department (AGFD) from 2012 to 2014 (AGFD 2015) and provided the opportunity to estimate an individual travel cost model of anglers at Lees Ferry. We used standard count data models (Shaw 1988; Hellerstein and Mendelsohn 1993; Englin and Shonkwiler 1995; Cameron and Trivedi 1998) to estimate how individual angler demand (i.e., angling trips per year) was affected by price and other parameters of recreational demand.

METHODS

Demand for nonmarket recreational activities, such as angling at Lees Ferry, is estimated by using revealed-preference or stated-preference methods. We used the travel cost method, which is a common revealed-preference approach (Parsons 2014). The general assumption is that the number of trips taken by an angler over a specified time period will decrease as the costs of those trips increase and as the net benefits of substitute opportunities become relatively high. Travel cost is estimated based on the distance traveled and the opportunity cost of time during travel. The individual observation travel cost model estimates the number of individual trips taken over a specified time period (i.e., demand) as a function of travel cost and other explanatory variables,

$$y_i = (x_i; \beta), \tag{1}$$

where y_i is the estimated number of trips taken by an individual to the site of interest, x_i are the explanatory variables, and β are the estimated coefficients. Explanatory variables include travel cost, income, availability of substitutes, demographic characteristics, and recreational site quality (Martínez-Espiñeira and Amoako-Tuffour 2008).

Estimation of a travel cost model by using on-site, secondary recreation data presents unique challenges (Martínez-Espiñeira and Amoako-Tuffour 2008; Bowker et al. 2009; Heberling and Templeton 2009; Benson et al. 2013; Neher et al. 2013). First, the dependent variable takes the form of a nonnegative integer (e.g., number of trips). Only individuals that participate in the recreational activity at least one time are included in the sample. A zero-truncated Poisson or negative binomial model allows for this type of truncated count data (Grogger and Carson 1991). Second, recreation data are typically overdispersed, with the variance of the dependent variable being greater than the mean (Haab and McConnell 2002; Martínez-Espiñeira and Amoako-Tuffour 2008; Heberling and Templeton 2009; Neher et al. 2013); this is because a few anglers take many trips, whereas most anglers take very few. In this case, a Poisson model is overrestrictive. However, use of a negative binomial regression model accounts for the overdispersion by estimating a dispersion parameter (α) with the negative binomial equal to the Poisson model as α = 0 (Grogger and Carson 1991). Another challenge of secondary recreation data is that anglers who participate in multiple trips are more likely to be surveyed, which results in endogenous stratification (i.e., oversampling of the more frequent recreation users; Englin and Shonkwiler 1995). Englin and Shonkwiler (1995) corrected for endogenous stratification in their estimation of recreational demand by using a zero-truncated negative binomial model. We similarly utilized a zero-truncated negative binomial model to account for endogenous stratification. The probability that a given angler takes y_i number of trips is

$$h(y_i|X_i) = \frac{y_i \Gamma(y_i + 1/\alpha_i)\alpha_i^{y_i}\lambda_i^{y_i-1}(1+\alpha_i\lambda_i)^{-(y_i+1/\alpha_i)}}{\Gamma(y_i+1)\Gamma(1/\alpha_i)}. \quad (2)$$

The likelihood function for the model is

$$\begin{aligned}\log_e L = \sum_{i=1}^{n} \{ & [\log_e y_i] + \log_e[\Gamma(y_i + \alpha_i^{-1})] - \log_e[\Gamma(y_i+1)] - \\ & \log_e[\Gamma(\alpha^{-1})] + [y_i \cdot \log_e \alpha_i] + [(y_i - 1)\cdot \log_e \lambda_i] \\ & -[(y_i + \alpha_i^{-1}) \cdot \log_e(1+\alpha_i\lambda_i)]\},\end{aligned} \quad (3)$$

where $\Gamma(\cdot)$ is the gamma function,

$$\lambda_i = \exp(\beta_0 + \beta_{TC}TC + \ldots + \beta_i X_i), \quad (4)$$

with TC = travel cost; and β_{TC} = the estimated travel cost coefficient. The optim routine in R (R Core Team 2014) was used to estimate (via maximum likelihood) the dispersion parameter α and the vector of explanatory variable coefficients (β).

The expected number of angler trips (conditional mean) is

$$E(y_i|x_i) = \lambda_i + 1 + \alpha_i\lambda_i. \quad (5)$$

The consumer surplus, or value per trip, is

$$\text{Consumer surplus} = -1/\beta_{TC}, \quad (6)$$

where β_{TC} is the estimated travel cost coefficient (Creel and Loomis 1990).

The confidence intervals (CIs) for consumer surplus estimates were generated by using SEs attained through nonparametric bootstrapping methods as previously described (Kling and Sexton 1990; Martínez-Espiñeira and Amoako-Tuffour 2008; Neher et al. 2013). Each consumer surplus estimate was generated by using 1,000 replicates with a 95% confidence level. Increasing the replicates did not change the consumer surplus point estimate or the CI range.

Data sources.—Data for this study originated from an AGFD on-site creel survey (hereafter, "survey") of anglers at Lees Ferry (n = 2,192, with a response rate close to 100%). The survey monitored angler use and the condition of the fishery below GCD (Rogowski et al. 2014). Surveys at Lees Ferry have historically collected recreational angling catch data (e.g., number caught, species, and angler effort), angler demographic data, and angler preference information. The survey aids in monitoring the Rainbow Trout population, including the effects of GCD operation on population demographics.

Lees Ferry is a historical Colorado River crossing with a boat ramp that allows anglers to travel by motorized watercraft approximately 24 km upstream to just below GCD. Walk-in anglers access the Colorado River near the boat ramp and dock as well as above and below the confluence with the Paria River (Figure 1). Prior to 2011, the survey primarily included anglers at the Lees Ferry boat ramp (i.e., the access point). During 2011, anglers using walk-in access sites (walk-in anglers) were added to the survey; in 2012, data on angler home zip codes were included. These data, along with the number of individual angler trips taken within the preceding 12 months, allowed us to estimate angler demand with an individual observation travel cost model.

Access point surveys and walk-in surveys were conducted throughout the calendar year during 2012–2014. However, due to budgetary and logistical shortfalls, angler surveys were not conducted in January 2012 or May–September 2012. On average, six random surveys occurred each month: three on weekdays and three on weekends. In fall 2014, stratification was shifted to two weekdays and four weekend days per month to reduce variance and improve angler estimates. An attempt was made to survey all anglers that utilized Lees Ferry during each survey period, including four different angler types: guided anglers at the access point, nonguided anglers at the access point, walk-in anglers above the Paria River confluence, and walk-in anglers below the Paria River confluence. Fishing regulations differ upstream and downstream of the Paria River confluence. Upstream of the confluence, only artificial lures with barbless hooks are allowed, and possession of Rainbow Trout larger than 35.5 cm is prohibited.

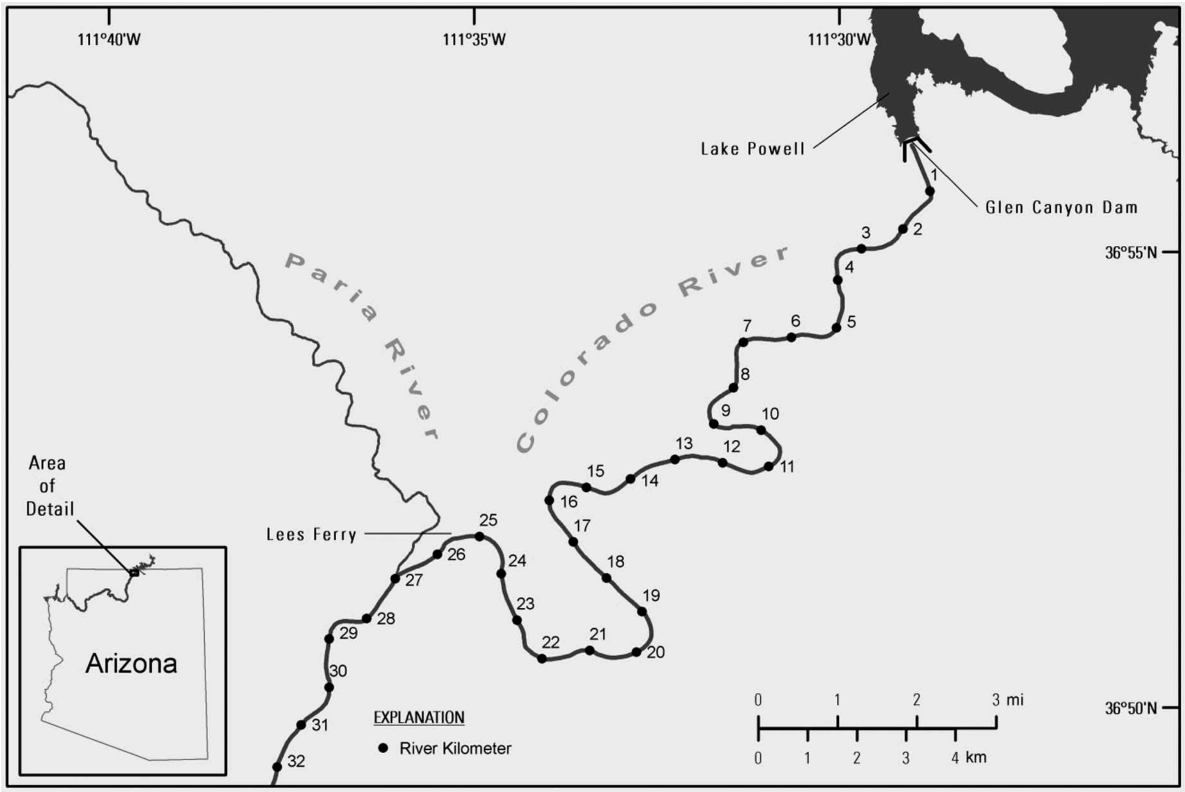

FIGURE 1. Map showing the Lees Ferry area of the Colorado River, Arizona, extending from Glen Canyon Dam to just beyond the Paria River confluence.

Downstream of the confluence, bait fishing is allowed, and all sizes of Rainbow Trout may be possessed. The difference in regulation is an attempt to encourage the harvest of Rainbow Trout downstream of the Paria River confluence in order to reduce the number of trout downstream, thereby lessening their potential effects on the Humpback Chub *Gila cypha*, which is listed as endangered under the U.S. Endangered Species Act (Bureau of Reclamation 2011).

Empirical model.—The dependent variable in the individual travel cost model was the number of individual angler trips to Lees Ferry over a 12-month period. We omitted repeated measures from respondents within a given calendar year. Similar to Englin and Shonkwiler (1995) and as suggested by Blaine et al. (2015), we also omitted data from respondents reporting a number of trips greater than 3 SDs from the mean (29.2 trips) in a calendar year; exclusion of those data allowed us to reduce concerns about recall and potential model specification issues with large integers. Approximately 99% of the sampled respondents reported trips less than 3 SDs from the mean in a given calendar year. Model specification improved when we excluded angler-reported trips greater than 10. However, the estimates of β_{TC} were robust under truncation to this point, with benefit estimates varying no more than 6%. After annual trips greater than 3 SDs from the mean were removed from the data set, we calculated that Lees Ferry anglers averaged 3.08 trips over a 12-month calendar year. Unlike national park visitation, which may occur once annually or even less frequently (Heberling and Templeton 2009; Neher et al. 2013), anglers take numerous trips over a year, resulting in sufficient variation in the unaltered dependent variable for model specification. With the proximity of Lees Ferry to national parks and monuments, there are undoubtedly anglers who participate in multiple-destination trips. The inclusion of multiple-destination trips will tend to upwardly bias the estimated benefits. The remote location, average annual number of fishing trips per angler, and specific skill set that is required to fish at Lees Ferry potentially suggests that more angling trips are single destination than "general" recreation at national parks. However, although there was insufficient survey information to discern single- and multiple-destination trips, we did limit respondents to regional anglers (one-way trip distance = 800 km) in an attempt to reduce the likelihood of multiple-destination trips (Martinez-Espineira and Amoako-Tuffour 2008; Blaine et al. 2015). Given the remoteness of Lees Ferry but the relatively high average number of annual trips, it seems reasonable that regional anglers participating in multiple-day trips would drive 800 km one way for a single-destination trip. We test the sensitivity to this assumption when reporting the model results.

Travel cost for each angler was derived based on the respondent's home zip code. We used the R package "ggmap" (Kahle and Wickham 2013) to identify travel distance (shortest road distance) in Google Maps from Lees Ferry (zip code 86036) to the respondent's home zip code. Google Maps identifies the starting and ending locations for a zip code as the centroid of the zip code "area." There is no consensus in the literature when estimating travel cost per kilometer (Blaine et al. 2015; Hang et al. 2016). Hang et al. (2016) recommended that fixed cost be excluded from travel-cost-per-kilometer estimates. Following Hang et al.'s (2016) recommendation and as in Neher et al. (2013) and Benson et al. (2013), we conclude that variable cost is the appropriate measure and that travel occurred by vehicle at the same variable cost per mile (14.6 cents/kilometer; Internal Revenue Service 2014). This rate is consistent with the operating cost of 12.7 cents/kilometer in 2013 and 11.8 cents/kilometer in 2014 (AAA 2013, 2014). The opportunity cost of time was included in the model at one-third the wage rate—or the respondent's estimated annual household income divided by 2,080 h (Englin et al. 1998; Blaine et al. 2015). Additional expenditures were included in the travel cost variable. Access fees of $15 per private vehicle and $16 per vessel were included in the cost variable for anglers (National Park Service 2015). For guided anglers, the cost of a full day of angling upstream of the access point was $350 per person (Lees Ferry Anglers 2015). This method does not account for the cost of multiple days of guided angling, lodging, or anglers' reduced cost as a result of multiple persons and/or days. Excluding the cost of additional days of angling or the cost sharing that may occur between anglers could have a counteracting effect, but the survey information did not allow for such an analysis. The annualized cost of motorized watercraft for nonguided anglers at the access point was not considered a variable cost and therefore was not included in the model. In addition to own price (travel cost), income is a determinant of recreational demand. Because income was not a variable in the survey, median income (2014 U.S. dollars) by zip code based on U.S. Census data (U.S. Census Bureau 2014) was used as a proxy for income (Heberling and Templeton 2009; Neher et al. 2013). Substitute angling price was not included in the model. As stated by Englin et al. (1998) and Von Haefen (2002), own price and income are sufficient to estimate welfare when only a single site is of interest.

Additional explanatory variables assessed in the model included angler demographic information and gear type. Age was evaluated using a dummy variable, with two categories (adult or retired). Gear type (fly fishing or other [spinner or bait]) was also assessed by using a dummy variable in the model. Although Bishop et al. (1987) reported that the size and number of fish caught were important attributes for anglers, CPUE was not included in the model due to potential issues with endogeneity (Englin et al. 1997). An additional dummy variable was included in the model to account for restricted access to Lees Ferry via U.S. Highway 89. In winter 2014, part of U.S. Highway 89 collapsed between Page, Arizona, and Lees Ferry, which increased travel time by approximately 45 min via the alternate route (Google Maps).

Important seasonal aspects of angling at Lees Ferry also impact demand: exogenous factors such as weather, Colorado River flows, and adaptive management experiments have been identified as central attributes influencing angler behavior (Bishop et al. 1987). The number of angler trips in this study was associated with season; higher numbers of trips occurred in spring and fall, coinciding with an average daily maximum temperature of 25°C. Angler trips decreased in the summer and winter, when daily maximum temperatures were 38°C and 11°C, respectively. Average daily flows at Lees Ferry are bound by the GCD operational regime identified by the Bureau of Reclamation (1996) and follow a distinct seasonal pattern. Higher flows in the summer and winter meet seasonal demand for power; over the sample period, the average flow was 354 m^3/s in summer and winter compared with 252 m^3/s in spring and fall. Furthermore, HFEs have recently been conducted during the fall, with an upper magnitude of 1,274 m^3/s and a duration of 96 h (Bureau of Reclamation 2015). Colorado River flows constrain the ability of anglers to approach the shore and to navigate watercraft in GCNRA above the access point. Flow levels that are too low impede upstream travel, whereas flows that are too high restrict the type of watercraft (i.e., engine size) that can be used (National Park Service 2014). Flows were obtained in 15-min increments from the U.S. Geological Survey (USGS) gauging station (09380000) at Lees Ferry. Daily average flows were correlated with season (spring: Spearman's rank correlation [ρ] = –0.38; summer: ρ = 0.46; fall: ρ = –0.37; winter: ρ = 0.43; $P < 0.01$). Thus, to allow for identification of a seasonal effect on demand, we included dummy variables for season in the model instead of data on flow levels. Seasons were grouped into 3-month categories that encapsulated the distinctly seasonal nature of Colorado River flows, weather, and visitation rates: spring included March–May, summer encompassed June–August, fall included September–November, and winter was defined as December–February.

Survey data were from a census of anglers on a given day. Individual anglers were surveyed. No attempt was made to separate the respondents by household. Groups of anglers average approximately three individuals (Rogowski et al. 2015); therefore, some of the individuals surveyed may have been members of the same household. Without additional information, we were unable to identify which anglers were from the same household. Demand and its determinants are likely similar among members of the same household; therefore, inclusion of multiple respondents from the same household creates a "cluster" effect, deflating model coefficient SEs and inflating the t-statistics and P-values (Cameron and Miller 2015). To test for potential model estimation bias, we made the assumption that assemblies of anglers consisted of an average of three individuals. We ordered the data by date and divided the data into three groups by drawing every

TABLE 1. Summary descriptive statistics (means with SDs in parentheses) for the variables assessed in the individual travel cost model for the trout fishery at Lees Ferry, Colorado River. Data are presented for the aggregate sample and for each angler type.

Variable	Description	Aggregate sample	Angler type: Guided at access point	Nonguided at access point	Walk-in above the Paria River confluence	Walk-in below the Paria River confluence
Annual trips	Number of angling trips to Lees Ferry in the past 12 months	3.50 (4.02)	1.91 (2.24)	4.33 (4.37)	3.76 (4.04)	4.83 (5.32)
Distance	One-way vehicle travel distance (km)	401 (153)	468 (114)	386 (151)	401 (150)	230 (142)
Income	Annual income by zip code of residence (thousands of U.S. dollars)	60.5 (20.9)	65.4 (23.5)	59.8 (19.3)	60.0 (19.7)	47.5 (13.4)
Age	Assigned a value of 1 if retired; assigned a value of 0 if adult	0.39 (0.49)	0.51 (0.50)	0.37 (0.48)	0.33 (0.47)	0.14 (0.35)
Fly fishing gear	Assigned a value of 1 if fly fishing gear; assigned a value of 0 if other gear (spinner and bait)	0.66 (0.47)	0.87 (0.33)	0.52 (0.50)	0.92 (0.27)	0.10 (0.31)
Highway 89 closure	Assigned a value of 1 if U.S. Highway 89 was closed; assigned a value of 0 if U.S. Highway 89 was open	0.61 (0.49)	0.59 (0.49)	0.61 (0.49)	0.50 (0.50)	0.86 (0.35)
Spring	Assigned a value of 0 if categorized as spring	0.50 (0.50)	0.59 (0.49)	0.43 (0.50)	0.60 (0.49)	0.33 (0.47)
Summer	Assigned a value of 1 if categorized as summer	0.14 (0.35)	0.11 (0.31)	0.14 (0.34)	0.04 (0.19)	0.48 (0.50)
Fall	Assigned a value of 1 if categorized as fall	0.17 (0.37)	0.14 (0.35)	0.21 (0.41)	0.17 (0.38)	0.06 (0.24)
Winter	Assigned a value of 1 if categorized as winter	0.19 (0.39)	0.16 (0.37)	0.22 (0.42)	0.19 (0.42)	0.13 (0.34)

third individual from the sample, with the first, second, and third entries of the sample as starting points. We then applied nonparametric bootstrapping to estimate the SEs of benefit estimates for each sample. Overlapping CIs indicated that there was no significant difference in aggregate model benefit estimates.

The model was estimated for the aggregate sample of anglers at Lees Ferry and separately for each type of angler. Anglers were grouped into four types: anglers that used guided watercraft at the access point (n = 570), anglers that used nonguided watercraft at the access point (n = 743), walk-in anglers above the Paria River confluence (n = 281), and walk-in anglers below the Paria River confluence (n = 163; Table 1). This approach allowed us to identify important variables that were specific to each angler type.

RESULTS

Model results for the variables associated with demand for angling at Lees Ferry are presented for the overall sample and for each angler type (Table 2); we also report the estimates of economic benefit. The zero-truncated negative binomial model accounted for overdispersion and endogenous stratification (Martínez-Espiñeira and Amoako-Tuffour 2008; Heberling and Templeton 2009). The difference between the mean (3.50 trips) and SD (4.02) of the dependent variable indicated overdispersion (Table 1). Although the model accounted for endogenous stratification, this correction did not improve model specification; zero truncation may alleviate the need for the modification (Donovan and Champ 2009).

The expected annual number of trips decreased with increasing cost of travel to Lees Ferry, resulting in a downward-sloping demand curve. Guided anglers at the access point and walk-in anglers above the Paria River confluence had larger absolute values of β_{TC} than the other angler types, indicating that demand was more price-elastic (responsive to travel cost). Overall, the expected number of annual trips increased with increasing income, as is expected with a normal good. However, detection of an inverse or nonsignificant relationship between trip demand and income in travel cost

TABLE 2. Results of the zero-truncated negative binomial model (estimated regression coefficients with robust SEs) for the number of annual angling trips taken to the Lees Ferry trout fishery (2012–2014) for the aggregate model and for each angler type. Asterisks indicate significant coefficients (*$P < 0.10$; **$P < 0.05$; ***$P < 0.01$). Interaction terms are season × travel cost and were only included in the aggregate model.

	Aggregate model		Guided at access point		Nonguided at access point		Walk-in above the Paria River confluence		Walk-in below the Paria River confluence	
Variable	Value	SE	Value	SE	Value	SE	Value	SE	Value	SE
Constant	–1.882***	0.250	1.251*	0.723	–2.863***	0.557	–2.112	1.675	–0.351	1.451
Travel cost (TC)	–0.004***	0.0002	–0.010***	0.001	–0.005***	0.001	–0.010***	0.001	–0.006***	0.002
Income	0.006***	0.002	0.020***	0.003	0.012***	0.003	0.015***	0.005	–0.023***	0.008
Age	0.323***	0.064	0.436***	0.132	0.290***	0.091	0.103	0.162	–0.348	0.319
Fly fishing gear	0.224***	0.066	0.078	0.194	0.348***	0.086	1.118***	0.303	–0.629	0.478
Highway 89 closure	0.224***	0.068	0.041	0.146	0.312***	0.096	0.140	0.160	–0.834**	0.351
Summer	0.209	0.147	–0.174	0.227	–0.146	0.138	0.594	0.366	0.389*	0.227
Fall	0.072	0.158	0.207	0.184	0.131	0.113	–0.069	0.201	0.469	0.424
Winter	–0.235*	0.136	0.830***	0.180	–0.007	0.114	0.056	0.191	0.553*	0.314
Summer × TC	–0.001	0.0005	–	–	–	–	–	–	–	–
Fall × TC	0.000	0.0005	–	–	–	–	–	–	–	–
Winter × TC	0.002***	0.0004	–	–	–	–	–	–	–	–
Alpha (α)	21.319***	4.811	15.823**	6.944	45.460*	24.423	16.901	29.230	45.458	61.313
Negative log-likelihood	3,392		703		1,687		554		381	
Expected number of annual trips	2.92		1.73		4.03		3.05		4.13	
Sample size	1,757		570		743		281		163	

studies is common (Martínez-Espiñeira and Amoako-Tuffour 2008; Blaine et al. 2015). Higher income could give anglers the ability to choose among substitute opportunities (Blaine et al. 2015) and therefore travel to other sites. We observed this result, an inverse relationship between trip demand and income, with walk-in anglers below the Paria River, the sample with the smallest average income.

We found that angler age (i.e., whether or not an angler was considered retired) was also significant, as higher numbers of trips were taken by older anglers overall and for anglers fishing at the access point.

Generally, the expected number of annual trips was higher for anglers using a fly lure when surveyed than for anglers using other gear types (anglers above the Paria River confluence are only allowed to use fly and spinner gear, while those below the confluence are allowed to use fly, spinner, and bait gear). This relationship was significant for nonguided anglers at the access point and for walk-in anglers above the Paria River confluence but not for guided anglers at the access point or walk-in anglers below the confluence. The expected number of trips increased with the closure of U.S. Highway 89; this relationship was evident for nonguided anglers at the access point. Such a finding is counterintuitive as closure of the highway increased travel costs for some anglers. Restricted access may discourage less-frequent anglers. The expected number of trips decreased with highway closure for walk-in anglers below the Paria River confluence. The expected annual number of trips for guided anglers at the access point and walk-in anglers above the Paria River confluence was not affected by the closure of Highway 89.

Seasonal use of Lees Ferry by anglers followed a predictable pattern, with the highest use detected in spring (April–May) and fall (September–October), although use occurs throughout the summer (Bureau of Reclamation 2011). The effect of season (summer, fall, or winter) was unique to each modeled angler type. Overall, the expected number of annual trips was higher for anglers that were surveyed during summer than for anglers surveyed during fall and winter; thus, avid anglers may be more likely to participate in "off-season" trips. This relationship was observed for walk-in anglers but not for guided or nonguided anglers at the access point. Alternatively, the expected number of annual trips was greater for guided anglers at the access point during fall and winter. To estimate the seasonal influence of travel cost on demand for annual trips, we included three interaction terms in the aggregate model: summer × travel cost; fall × travel cost; and winter × travel cost. Demand for trips was more price-elastic in summer and less price-elastic in winter.

Economic Benefit Estimates

The estimated model allowed for the calculation of net economic benefit (consumer surplus) of angling at Lees

TABLE 3. Bootstrapped estimates of the per-trip benefit (2014 U.S. dollars) of angling at Lees Ferry based on the aggregate model (CL = confidence limit). The per-trip benefits in summer and fall were not significantly different from spring.

Statistic	Spring	Summer	Fall	Winter
Upper 95% CL	$277	$265	$337	$577
Point estimate	$237	$210	$264	$408
Lower 95% CL	$197	$156	$190	$239

Ferry per trip for each season (Table 3) and angler type (Table 4). Because interaction terms were included in the aggregate model, the seasonal interaction coefficients were "adjustments" to β_{TC}, estimating the difference in demand for annual trips relative to season. The larger the absolute value of β_{TC}, the greater was the price elasticity of the expected annual trips. The economic benefit was $237 per trip for the spring season ($-1/\beta_{TC}$), $210 per trip for the summer ($-1/[\beta_{TC} + \beta_{SummerInteraction}]$), $261 per trip for the fall ($-1/[\beta_{TC} + \beta_{FallInteraction}]$), and $399 per trip for the winter ($-1/[\beta_{TC} + \beta_{WinterInteraction}]$). Travel cost coefficients for the summer and fall season were not significantly different from the spring season coefficient in the aggregate model. Estimated benefits ($-1/\beta_{TC}$) varied by angler type, with a range of $99 per trip for guided anglers at the access point to $203 per trip for nonguided anglers at the access point.

Nonparametric bootstrapping was used to estimate the CIs of benefit estimates for the aggregate model and for angler types (Kling and Sexton 1990; Martínez-Espiñeira and Amoako-Tuffour 2008; Neher et al. 2013). In the aggregate model, bootstrapped seasonal benefit estimates overlapped at the 95% level of confidence. At the 95% confidence level, bootstrapped benefit estimates overlapped among all angler types; the benefit estimate for walk-in anglers above the Paria River confluence was not statistically different from zero. Although the bootstrapped values did not indicate significant differences between benefit estimates for seasons or angler types, the means were significantly different when Welch's *t*-test was applied, and the results do provide insight into the distribution of relative benefits among seasons and among angler types.

TABLE 4. Bootstrapped estimates of the per-trip benefit (2014 U.S. dollars) of angling at Lees Ferry based on the model for each angler type (CL = confidence limit).

Statistic	Guided at access point	Nonguided at access point	Walk-in above the Paria River confluence	Walk-in below the Paria River confluence
Upper 95% CL	$161	$267	$127	$1,289
Point estimate	$103	$206	$104	$208
Lower 95% CL	$45	$144	$82	–$873

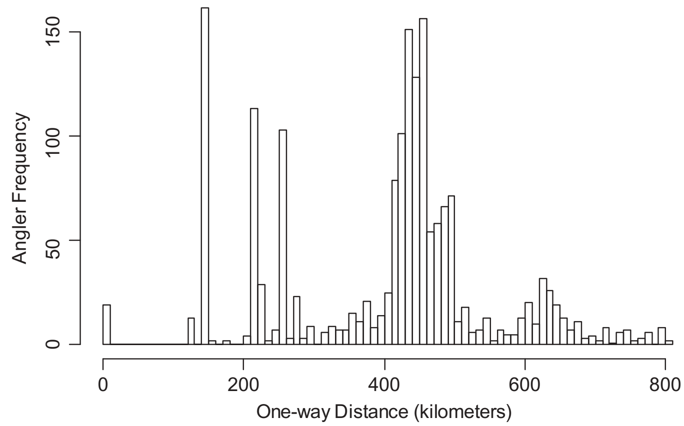

FIGURE 2. Histogram of distances traveled by unique individual anglers to Lees Ferry on the Colorado River, Arizona.

Segmenting anglers by distance is also an important consideration. In the aggregate model, we thought it reasonable that regional anglers participating in multiple-day tips would drive 800 km one way for a single-destination trip. Examination of angler frequency by distance traveled to Lees Ferry indicated that there were groupings of anglers segmented by geography (Figure 2). Truncation of distance at the noticeable breaks (400, 600, and 800 km) resulted in aggregate angler consumer surplus estimates of $330, $275, and $262 per trip, respectively. We did not adjust travel cost between groups to account for alternative modes of travel or travel time given the limited survey information, the remote location of Lees Ferry, and the fact that the sample was limited to regional anglers (truncated at 800 km). The expected number of annual trips was greater when we considered only those anglers within a 400-km distance (five annual trips) than when anglers within 600 and 800 km were also included (three annual trips). The effects of income, use of fly lures, and age were positive and significant when the expected number of annual trips was modeled for each group of anglers truncated by distance traveled. However, seasonal parameters significantly determined demand only when we included anglers within 600 and 800 km, with the expected number of annual trips being greater during the fall and winter seasons. These results point to the avidity of anglers within 250 km of Lees Ferry and indicate that the segmentation of anglers by distance has a limited impact on aggregate consumer surplus estimates.

DISCUSSION

We applied an individual travel cost model to estimate the economic benefits of angling at Lees Ferry for each season and angler type. Net economic benefits varied by season. The point estimates of the bootstrapped consumer surplus and the estimated number of annual angling visits to Lees Ferry were used to calculate the overall annual economic value of angling. The number of anglers visiting Lees Ferry in 2014 was conservatively estimated at 10,454 (Rogowski et al. 2015). With an average economic value of $262 per trip (the average value across seasons and angler types), the total annual economic value of the Lees Ferry fishery is estimated at $2.7 million (average net economic benefit was estimated from β_{TC} without seasonal interaction variables).

Variation in resource and policy attributes and differences in methodology preclude a direct comparison of our results to past research by Richards and Wood (1985) and Bishop et al. (1987). However, while not directly comparable, our consumer surplus estimate of $262 per angler trip is similar in magnitude to the most recent research: Bishop et al. (1987) estimated consumer surplus values of $225 per trip for fluctuating flows and $281 per trip for constant flows (estimates are in 2014 dollars; the consumer price index [Federal Reserve Bank of St. Louis 2015] was used to escalate the net economic benefit estimates from Bishop et al. 1987). These results suggest that angler economic value per trip is similar to estimates (Bishop et al. 1987) obtained when fishery characteristics were considerably different. After the mid-1990s reduction in diurnal Colorado River flow variation, Rainbow Trout were able to maintain a naturally reproducing population, and stocking was discontinued in 1998 (McKinney et al. 2001). In an effort to maintain larger fish within the system, Rainbow Trout harvest regulations in terms of fish size and number have become more restrictive since the research by Bishop et al. (1987). In addition, declining Rainbow Trout size and fluctuation in CPUE may have led to a generally decreasing trend in angler use (Loomis et al. 2005). The similarity in benefit estimates between the present study and the Bishop et al. (1987) study, even with distinct changes in the fishery, suggests that future research could include a multivariate analysis of angler participation and Rainbow Trout population demographics (e.g., size and number) to better identify how angler demand is influenced by the quality of the fishery.

The individual travel cost model highlights specific differences among angler types and across seasons. Depending on the angler type, the expected number of annual trips was explained by the cost of travel, angler income, angler age, angler skill and gear type, and season. Based on historical use and bootstrapped benefit estimates, the total seasonal net economic value of angling in 2014 was $0.8 million for the spring season (3,491 estimated angler-days at $237 per day), $0.8 million for the fall (3,059 estimated angler-days at $264 per day), $0.4 million for the summer (2,952 estimated angler-days at $210 per day), and $0.4 million for the winter (952 estimated angler-days at $408 per day; Bureau of Reclamation 2011; Rogowski et al. 2015). These differences reflect angler preferences for season. We assume that anglers are choosing to fish more in the spring and fall due to the more favorable weather conditions. Commercial fishing guides have reported that fewer people book trips during HFEs; annually, in 2012–2014, HFEs with an upper magnitude of 1,274 m^3/s and a duration of 96 h occurred in November, when angler usage is known to be relatively high. Thus, operations of the dam can directly affect angling quality and participation at Lees Ferry. Our results provide insight into how seasonal GCD operations, adaptive management experiments, and other management actions can impact the economic benefit of angling at Lees Ferry. Given the seasonal preferences of anglers and given the Bishop et al. (1987) results demonstrating the influence of Colorado River flows on angler benefit, an up-to-date investigation into the effect of GCD operations on angler consumer surplus is warranted. An understanding of the relationships between downstream resources is important given the potential climate-driven changes in Colorado River basin hydrology and subsequent management of downstream resources, including the effects of GCD operation, HFE frequency and magnitude, and other potential adaptive management experiments in GCNRA and GCNP.

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