The Effect of Fluctuating Water Levels on Reservoir Fishing

Paul M. Jakus, Paula Dowell, and Matthew N. Murray

The effect of Tennessee Valley Authority reservoir water levels on recreational fishing is evaluated. Data were collected in east Tennessee during March through August of 1994-97. Water levels were not a major barrier to participation during the six-month period, but levels did affect the number of trips taken by anglers. Maintaining lakes at full pool for one additional summer month would result in an additional one-third trip per angler, or an additional 87,000 trips in the study region. The average net benefit of a full pool is $1.82 per angler, or an aggregate benefit of approximately $476,500 in the region.

Key words: lake levels, recreation, reservoir fishing, water levels

Introduction

The Tennessee Valley Authority (TVA) system of dams and reservoirs is designed to provide the Tennessee Valley with flood control, navigation along the Tennessee River, power generation, and economic development in the region. Current TVA policy begins lake drawdowns on August 1 of each year to generate electricity and provide downstream flood control. The drawdown date was chosen in 1990, after an intensive review of reservoir operations by TVA in cooperation with representatives from local government, businesses, and the general public. TVA personnel have declared the process and its outcome a model of success and cite its applicability to other water management agencies facing controversy (Ungate).

1 Controversy over reservoir drawdown policies is not new or unique to TVA, and a small economic literature addressing the issue has developed. A sampling of recent literature includes Ward, who estimated a four-reservoir demand system to gauge the economic losses of draining three reservoirs in New Mexico. Cordell and Bergstrom used contingent valuation methods to estimate the impact of TVA drawdown policies on four TVA lakes in North Carolina. Cameron et al. examined recreationists' actual behavior in the Columbia River Basin in the Pacific Northwest, finding that low water levels affected the decision to recreate at all, as opposed to affecting the number of times a lake was visited. Ward et al. used a constant elasticity of substitution (CES) demand system to evaluate various water level policies at New Mexico reservoirs. Fadali and Shaw looked at a remote lake in central Nevada, using a nested logit model to estimate anglers' willingness to pay to prevent water volume losses that would cause the fishery ecosystem to collapse. Shaw et al. estimated angler losses of a fish kill that resulted from draining a lake in northern Nevada.
But the August 1 drawdown remains controversial, especially among users of tributary lakes at the upper end of the Tennessee Valley watershed. These lakes tend to have deeper channels with shallower, high elevation coves. The drawdown leaves many coves and boat ramps at these lakes landlocked for much of the year, or the drawdown results in a long mud flat eventually leading to water. An extensive number of land parcels are exposed to these mud flats, which depress property values. Recreational users, including anglers, may find access limited or precluded through the drawdown. A recent study found that delaying drawdown until October 1 on two major tributary lakes could have an economic impact to just six surrounding counties as high as $7 million, as people increase lake recreation in response to higher water levels (Murray et al.).

The effects of the drawdown policy are likely to differ across recreational activities. While some activities such as swimming are clearly impacted in a negative way, the effect that drawdowns have on sportfishing is in question. Some argue that drawdowns help anglers because fish become concentrated in smaller pools of water, improving fishing quality. Others contend that access issues are more important because dry boat ramps restrict the ability of reservoir anglers to launch boats, or that the aesthetic impact of a “bathtub ring” around the lake discourages recreational fishing.

A multi-year recreational fishing data set is used to evaluate the response of reservoir anglers to the TVA water management policy. Angler response is modeled with a combined multinomial site-choice/double-hurdle (MNL/DH) count-data trips model, following Shaw and Jakus. The MNL/DH modeling strategy allows us to model the effect of water levels not only on site choice (i.e., which reservoir to fish), but also on the “desire” to fish in reservoirs, where water levels may represent a site-quality hurdle. Finally, the modeling strategy allows estimation of the benefits to anglers under alternative water level policies.

This study contributes to the current body of research in several ways. First, changes in the operation of a “linked” reservoir system are evaluated with a “linked” site-choice/trips behavior model. The behavioral model allows anglers to choose from a variety of sites with differing site characteristics, and it can accommodate substitution among sites and changes in the total number of recreation trips. While Cameron et al. studied a linked reservoir system (the Columbia River Basin), their behavioral models were estimated for individual sites rather than allowing for substitution among sites.

Second, the policy scenarios considered here are consistent with those pursued by private-interest groups and are well within the experience of recreationists. “Extreme” policy scenarios, such as completely draining a lake (Ward) or killing all fish (Fadali and Shaw), are not considered. Further, we do not rely upon data based on hypothetical responses to hypothetical water levels (e.g., Cordell and Bergstrom; Cameron et al.).

Finally, TVA is nearing the end of a 10-year moratorium on changes in reservoir operations, so the lake level issue will once again be on the agenda of TVA policy makers and local interest groups. Given the sometimes contradictory goals of TVA, as well as the new regulatory environment of the power generation industry in which TVA must compete, it is important to identify the economic effects of changes in reservoir operations on lake users.
The Advantage of the Multinomial Logit/Double-Hurdle Approach

The MNL/DH model\(^2\) allows us to separate the sample of anglers into three groups. The first group is composed of reservoir users, those who actually fish in reservoirs of the TVA system. The second group is potential reservoir users, those who fish other types of water bodies but would consider fishing in reservoirs under circumstances favorable to them. These people might wish to fish in reservoirs but face a hurdle that prevents reservoir fishing, e.g., a site-quality hurdle caused by inadequate water levels which may limit access or increase the chance that a boat may strike a submerged object. The final group is composed of those anglers who would rarely, if ever, consider fishing in reservoirs (say, the die-hard fly-fisherman), and these individuals never get over this "participation" hurdle. The first hurdle is fundamentally economic: if site quality improves enough, the consumer will move from a corner solution (no trips) to an interior solution (nonzero trips). The second hurdle is fundamentally noneconomic: the feasible set of policy-relevant price/quality combinations is very unlikely to move the consumer from a corner to an interior solution.

The key advantage of the MNL/DH modeling strategy is that one can specify different data-generating mechanisms for the different hurdles that define each group. The probability of observing zero trips for any observation is composed of two parts: the probability that desired consumption is zero (the participation hurdle) plus the probability that desired consumption is positive, but another hurdle prevents consumption (the site-quality hurdle).

Following Shonkwiler and Shaw, let \(D_i\) represent the latent decision by person \(i\) to participate in reservoir fishing, with observed trips \(y_i = 0\) if \(D_i \leq 0\). Let \(\text{Prob}(D_i = 0) = \exp(-\theta_{i})\), where \(\theta_{i}\) is parameterized by \(\exp(Z_i'\gamma)\). \(Z_i\) is a vector of factors influencing the participation hurdle and can include individual specific variables such as demographics, so that \(\exp(-\theta_{i})\) measures the probability that a person with characteristics \(Z_i\) has no interest in taking reservoir fishing trips. Additionally, let \(\lambda_i\) be the Poisson parameter describing the number of reservoir fishing trips, where \(\lambda_i = \exp(X_i'\beta)\) and \(X_i\) is a vector of variables that influence the trip-making process. The probability that any person \(i\) is a nonuser with little or no interest in reservoir fishing is \(\exp(-\theta_{i})\), whereas the probability of a corner solution (potential user) is given by \([1 - \exp(-\theta_{i})] \times \exp(-\lambda_{i})\). This second probability is simply the product of the probability of clearing the participation hurdle and the probability that desired trips is zero (perhaps because of site quality reasons). Finally, the probability that observation \(i\) is a reservoir user (clearing both hurdles) is given by \([1 - \exp(-\theta_{i})] \times [1 - \exp(-\lambda_{i})]\).

Combining a multinomial logit site-choice model with a double-hurdle count-data model allows us to gauge the influence of water levels not only on site choice, but also on participation in reservoir fishing.\(^3\) To see this, recall that combined site-choice/trips models use some form of the inclusive value (IV) to act as the link between the site choice portion of the model and the trips/participation portion. The inclusive value is

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\(^2\)This section draws heavily upon Shonkwiler and Shaw, who provide a very lucid development of the double-hurdle count-data model, which can be extended to a mix of discrete and continuous distribution functions. Yen and Adamowicz, and Haab and McConnell also present hurdle count-data models.

\(^3\)A number of different versions of linked site-choice/trips models exist. See Parsons, Jakus, and Thomasi for a review of the most common.
calculated as \( IV_i = \ln \left( \sum_j \exp(\delta P_{ij} + W_j\tau) + 0.577 \right) \), where \( P_{ij} \) is the travel cost of person \( i \) to site \( j \), \( W_j \) is a vector of other characteristics of site \( j \), and \( \delta \) and \( \tau \) are the price and characteristics coefficients, respectively, estimated at the site choice portion of the model. By summing over all \( J \) sites, the inclusive value summarizes all site characteristics into a single utility index to be included as part of the \( X_i \) vector for the trips portion of the model.\(^4\) As an explanatory variable for \( \lambda_i \), a positive coefficient for \( IV_i \) is expected. For example, higher travel costs cause lower values of \( IV \) (utility) if the sign of \( \delta \) is negative. Theory suggests that lower utility implies fewer trips, so that \( \lambda \) (the trips measure) should be positively related to \( IV \). With respect to site-specific water levels appearing in the site-choice model, summer water levels above normal increase the utility index if the water level coefficient (\( \tau \)) is positive. One may gauge the impact of water levels on a reservoir user or potential user by determining the effect on \( \lambda_i \), and calculating the probabilities as described above.

**Study Area and Data Sources**

The study area consists of a set of 13 reservoirs located in a 34-county region of east Tennessee. Nearly all of the reservoirs are located adjacent to an interstate highway and stretch along a corridor from Bristol to Chattanooga, Tennessee. The reservoirs in the northeast portion of the study area are tributary reservoirs subject to relatively large drawdowns in the fall; the most popular tributary reservoirs are Cherokee, Douglas, and Norris reservoirs. Water levels on Norris Lake, for example, range from a March 1 elevation of 995 feet to a peak elevation of 1,023 feet about June 1. Douglas Reservoir enjoys 750,000 visitor-days per year, Cherokee 950,000 visitor-days, and Norris over 2 million visitor-days per year (Murray et al.).

Recreational fishing data were collected between 1994 and 1997, a four-year period. A random digit dial survey was used in each year to contact and identify people who fished in Tennessee.\(^5\) Once identified, anglers were asked about all fishing activities during the six-month time period (March 1 through August 31) immediately preceding the survey. We did not contact the same anglers each year, so we do not have a panel data set. The final data set is composed of 977 east Tennessee anglers from whom complete trip and income data were obtained.\(^6\) Not all anglers fished in reservoirs during the six-month period; they could have fished in private ponds, trout streams, or warmwater streams.

Daily water level information for each lake was obtained from the Tennessee Valley Authority. The four-year time period showed considerable variation in water levels for the tributary lakes. Figure 1 shows the daily elevations for a typical tributary lake, Norris Lake, located about 30 miles north of Knoxville, Tennessee. As seen from this graphic, 1996 and 1997 were relatively “normal” years as the reservoir filled during the spring. In 1994, however, the lake filled very rapidly, while in 1995 the lake filled very slowly. In 1994 and 1996 “full pool” was reached around May 15, whereas in 1995 and 1997 full pool was reached on roughly June 1. On August 1, TVA’s policy of maintaining

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\(^1\) Hausman, Leonard, and McFadden convert \( IV \) to a surplus measure and interpret it as a price index.

\(^2\) Details about each survey are available from the authors upon request.

\(^3\) The sample contained roughly the same number of observations for each year: 25.3%, 26.7%, 25.4%, and 22.6% from 1994, 1995, 1996, and 1997, respectively.
Figure 1. Water levels on Norris Lake, March 1–August 31, 1994–97

Figure 2. Water levels on Fort Loudon Lake, March 1–August 31, 1994–97
a full pool expires, and the agency begins unrestricted lake drawdown. Relative to the 1996 drawdown, the lake was drawn down swiftly in 1995 and 1997, while in 1994 it remained near full pool. The seasonal pattern of water levels on Norris was similar to that experienced by the other two major tributary reservoirs (Douglas and Cherokee).

For contrast, figure 2 shows the change in elevation for a typical "run-of-the-river" reservoir (Fort Loudon, located in Knoxville) not subject to large drawdowns. None of the downstream reservoirs have large drawdowns (on average, about 4–6 feet elevation change).7

The theoretical model and the data available to test the model do not correspond as closely as desirable. Given the decision to fish on a specific day, an angler is likely to make a site choice decision based on the conditions of that day, including water levels at all possible sites. Although daily water level measurements at each site are available, anglers' daily fishing decisions are not available. Instead, anglers' fishing decisions (the number of fishing trips to each site) are known only for the entire season. Consequently, it is necessary to compromise by converting daily water levels into measures that correspond to the available behavioral data.

The water level data must capture both the "fill" rate and the "drawdown" rate for each reservoir, so the periods April 15 through May 15 (fill) and August 1 through August 31 (drawdown) were chosen. Two types of measures were calculated. First, for each time period in each year, the average daily water elevation (measured in feet) was calculated. The water level characteristic for each reservoir was calculated as the deviation from the 1996 level. Water levels above those in 1996 were measured as positive values, whereas levels that were lower than 1996 had negative values. This deviation measure loses the within-month daily variation, but still serves as a measure of the magnitude to which reservoirs were above or below their 1996 levels. The second method, using simple dummy variables, goes further by dispensing with magnitudes altogether. Average monthly water levels greater than those occurring in 1996 were coded as 1, while those lower than observed 1996 levels were coded as -1. Water levels in 1996, and those equaling 1996 values, were coded as 0. The two measures allow us to ascertain if anglers respond to the magnitude of drawdowns, or if anglers respond to drawdowns more generally.

**Empirical Results**

The full sample for this study consisted of 977 east Tennessee anglers, of whom 55.2% were reservoir users.8 Simple statistics from the recreational data indicate that water levels may be important to anglers. Table 1 reports angler visitation to tributary reservoirs over the four-year study period. During the high pool water year in 1994, over 62% of anglers fished in reservoirs, whereas during the low pool water year of 1995, fewer than 50% of anglers fished in reservoirs. This finding provides evidence that water levels may be part of a significant site-quality hurdle as suggested by Cameron et al.

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7 The exception is Hiwasee Reservoir in the southwestern mountains of North Carolina, about one hour east of Chattanooga. While this lake is included in the study as an important potential substitute site, it receives only 1.5% of all trips made by east Tennessee reservoir anglers.

8 The data set is composed of cross-sectional data repeated each year for four years; thus an ideal empirical model would apply pseudo-panel data techniques to the MNL/DH model. The data are quite thin—977 observations total for all four years—so that measurement error for the set of cohorts defined for a pseudo-panel approach is likely to be severe (Collado).
Table 1. East Tennessee Angler Visitation to Reservoirs, by Year

<table>
<thead>
<tr>
<th>Year</th>
<th>Anglers Visiting Reservoirs (%)</th>
<th>Average No. of Visits to All Reservoirs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>62.3</td>
<td>16.40</td>
</tr>
<tr>
<td>1995</td>
<td>49.6</td>
<td>12.90</td>
</tr>
<tr>
<td>1996</td>
<td>54.0</td>
<td>15.32</td>
</tr>
<tr>
<td>1997</td>
<td>55.2</td>
<td>14.72</td>
</tr>
</tbody>
</table>

Further, the average number of trips by reservoir anglers was lowest in 1995 and highest in 1994 (table 1).

Site Choice Portion

As noted above, water levels during two time periods (April 15 through May 15, and August 1 through August 31) were used to characterize the spring “fill” and late summer “drawdown” phases of this reservoir characteristic. The models presented in table 2 differ depending upon whether the model uses the magnitude measure (the “magnitude model”) or the dummy variable measure (the “dummy variable model”). Other reservoir characteristics included travel cost, the number of boat ramps at each reservoir, and the average catch rate (summed over all species and averaged across anglers). A dummy variable indicating the presence/absence of a fish consumption advisory was the final reservoir characteristic. In both models, all coefficients for variables in the site choice portion of the model (other than the water level measures) had the expected sign and were statistically significant (table 2). Rising travel costs made a site less likely to be visited (the negative sign), more boat ramps—a measure of site access—made a site more likely to be visited (a positive sign), higher catch rates made a site more likely to be visited (a positive sign), and a fish consumption advisory made a site less likely to be visited (negative sign).

Focusing now on the role of water levels in site choice (table 2), a positive coefficient means that a site was more likely to be visited when water levels were above 1996 levels, whereas a negative coefficient means a site was less likely to be visited if water levels were above 1996 levels. Regardless of how the August water levels were measured, both site-choice models had coefficients that were positive and significant. Low water levels in the late summer negatively impacted site choice: relative to the 1996 water levels, low water made a site less likely to be visited, while higher water levels made a site more likely to be visited. The coefficient for spring water levels was negative in both

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9 The catch rate measure used in this study results in the errors-in-variables problem recently highlighted by Morey and Waldman. The solution proposed by these authors does solve this problem, but Train, McFadden, and Johnson demonstrate that the Morey-Waldman solution only works when there are no omitted site attributes, measurement error in other variables, or “other random events.” If these problems cannot be eliminated, then the Morey-Waldman method introduces correlation between the residuals and the catch rate coefficient. In effect, the analyst trades one type of bias for another. Train, McFadden, and Johnson conclude that the standard procedure “is consistent under weaker and more realistic assumptions...” The standard procedure is adopted for our study.

10 See Jakus et al., and Jakus, Dadakas, and Fly for other reservoir fishing models that have included fish consumption advisories as a site characteristic.
Table 2. Coefficient Estimates: Double-Hurdle Site-Choice/Trips Models for Reservoir Fishing

<table>
<thead>
<tr>
<th>Variable</th>
<th>Water Level Magnitude Model (deviation from 1996)</th>
<th>Water Level Dummy Variable Model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site Choice Portion:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Travel Cost</td>
<td>-0.041** (-9.12)</td>
<td>-0.041** (-9.21)</td>
</tr>
<tr>
<td>No. of Boat Ramps</td>
<td>0.030** (6.90)</td>
<td>0.028** (6.71)</td>
</tr>
<tr>
<td>Fish Consumption Advisory</td>
<td>-0.324** (-2.57)</td>
<td>-0.329** (-2.65)</td>
</tr>
<tr>
<td>Catch Rate</td>
<td>0.101** (3.00)</td>
<td>0.095** (2.40)</td>
</tr>
<tr>
<td>August Water Level Deviation</td>
<td>0.069** (1.99)</td>
<td></td>
</tr>
<tr>
<td>4/15–5/15 (Spring) Water Level Deviation</td>
<td>-0.053 (-1.50)</td>
<td>0.058* (1.71)</td>
</tr>
<tr>
<td>August Water Level Dummy</td>
<td></td>
<td>-0.176* (-1.93)</td>
</tr>
<tr>
<td><strong>Trip Frequency Portion:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>2.172** (8.89)</td>
<td>2.124** (6.83)</td>
</tr>
<tr>
<td>Inclusive Value (IV)</td>
<td>0.182* (1.73)</td>
<td>0.211 (1.42)</td>
</tr>
<tr>
<td>Income ($000s)</td>
<td>0.005** (1.98)</td>
<td>0.005* (1.88)</td>
</tr>
<tr>
<td><strong>Participation Portion:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>-0.383** (-3.85)</td>
<td>-0.383** (-4.13)</td>
</tr>
<tr>
<td>Own a Boat</td>
<td>0.323** (2.91)</td>
<td>0.323** (3.64)</td>
</tr>
<tr>
<td>College Education</td>
<td>0.330** (2.36)</td>
<td>0.330** (2.65)</td>
</tr>
<tr>
<td>Non-White</td>
<td>-0.294 (-1.58)</td>
<td>-0.294 (-1.43)</td>
</tr>
<tr>
<td>Live in Urbanized County</td>
<td>0.162 (1.51)</td>
<td>0.162 (1.29)</td>
</tr>
<tr>
<td>Dummy for 1994</td>
<td>0.067 (0.64)</td>
<td>0.067 (1.03)</td>
</tr>
<tr>
<td>Dummy for 1995</td>
<td>-0.174 (-1.11)</td>
<td>-0.174 (-1.60)</td>
</tr>
<tr>
<td>Dummy for 1997</td>
<td>-0.060 (-0.25)</td>
<td>-0.060 (-0.28)</td>
</tr>
<tr>
<td>No. of Observations</td>
<td>977</td>
<td>977</td>
</tr>
</tbody>
</table>

Notes: Single and double asterisks (*) denote significance at the $\alpha = 0.10$ and $\alpha = 0.05$ levels, respectively. Numbers in parentheses represent the ratio of a coefficient to its asymptotic standard error (standard errors were determined using White's general covariance matrix).

models, but was not statistically significant at conventional levels in the magnitude model.\textsuperscript{11}

Trip Frequency/Participation Portions

The information contained in the site-choice model is passed to the trip frequency model via the inclusive value (IV). The inclusive value contains both economic information (the effect of travel cost) and site quality information (e.g., the effect of water levels). The sign of the coefficient for inclusive value is positive in both models (table 2), as expected,

\textsuperscript{11} In contrast with low August water levels, low spring water levels (slowly filling reservoirs) provide excellent fishing in the cool, shallow waters along a reservoir edge.
but is statistically significant in only the magnitude model. Trip frequency also increases as income increases, where income is statistically significant in both models. In the participation portion of the model, anglers who owned a boat were more likely to participate in reservoir fishing than those anglers who did not own a boat. College-educated anglers were more likely to fish reservoirs relative to anglers with a high school education or less. Participation in reservoir fishing was independent of an angler’s race or whether the angler lived in an urban or rural county. Further, none of the yearly dummy variables for each year were statistically significant. This suggests that, other than water levels, there were no aggregate, systematic influences associated with any given year.

Which Water Level Model Is Appropriate?

It is not clear whether the magnitude model should be favored over the dummy variable model, or vice versa. (The models were not nested, so a simple likelihood-ratio test was not possible.) Coefficients for all water level variables have the expected sign in both models. The August water level measure is statistically significant in both models, while the spring water level measure is significant in only the dummy variable model (table 2). This might cause one to favor the dummy variable model, except that the inclusive value in the dummy variable model is insignificant. In contrast, the inclusive value is statistically significant in the magnitude model. This finding indicates that the additional information about the magnitude of water levels, as carried by the inclusive value, may be an important determinant of trip frequency over the fishing season.

The competing models may also be assessed according to their ability to accurately predict trips and participation probabilities. Evaluating the models at actual values of the sample data, both the magnitude model and the dummy variable model predicted the probability of participation in reservoir fishing reasonably accurately (table 3). The models also predicted the conditional and expected number of reservoir fishing trips accurately, where the values predicted by each model were extremely close to one another. Empirically, there appears to be little difference between the two models. The models do differ in their suitability for policy analysis. In particular, the dummy variable model does not allow one to test for the welfare effects of the key policy scenario: keeping full reservoir pools through the end of the summer. Strictly speaking, the best that can be done with the dummy variable model is to assess the welfare effects of keeping reservoirs above their 1996 levels, which is a very different policy scenario than that actually faced by decision makers. The remaining analysis, therefore, is restricted to the magnitude model (although welfare scenarios for the dummy variable model are available upon request from the authors).

Evaluating Alternative Water Level Scenarios

Two water level scenarios were considered in comparison to a “baseline,” where the baseline is the historically experienced water level in the sample. The first alternative scenario assumes that the August water levels experienced in 1996 provide a “standard” that could be achieved in August of each year. Relative to the water levels actually experienced during 1994–97, the 1996 standard represents higher water levels than
Table 3. Evaluating Mean Usage Probabilities Under the Magnitude Model and the Dummy Variable Model

<table>
<thead>
<tr>
<th>Formula</th>
<th>Water Level Dummy Variable Model</th>
<th>Sample Means</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prob(Nonuser) = exp(−θ)</td>
<td>0.4475</td>
<td>0.4473</td>
</tr>
<tr>
<td>Prob(Potential User) = (1 – exp(−θ))×exp(−λ)</td>
<td>6.0 × 10⁻⁷</td>
<td>7.23 × 10⁻⁷</td>
</tr>
<tr>
<td>Prob(User) = [1 − exp(−θ)]×[1 − exp(−λ)]</td>
<td>0.5525</td>
<td>0.5527</td>
</tr>
<tr>
<td>E(Trips</td>
<td>Trips &gt; 0)</td>
<td>14.61</td>
</tr>
<tr>
<td>E(Trips)</td>
<td>8.11</td>
<td>8.28</td>
</tr>
</tbody>
</table>

experienced in 1995 and 1997, and lower water levels than experienced in 1994. The second alternative is that advocated by local lake user groups: maintaining a full pool through the end of August. The full pool scenario is reasonably close to the water levels experienced in 1994. Neither policy scenario represents site quality levels that are beyond what anglers have already experienced.¹²

Water Levels as a Site-Quality Hurdle

In the MNL/DH model, the influence of water levels on participation is captured in the inclusive value (IV) index passed from the site choice portion to the hurdle portion. Following the formulas presented in the methodology section, the probabilities were calculated for: (a) any angler being a user (someone who fished in a reservoir), (b) a nonuser (someone who would not fish reservoirs regardless of the water level), and (c) a potential user (someone who would fish reservoirs if water levels were high enough) (table 3). Under all policy scenarios, the probability of being a nonuser is constant because the inclusive value index does not enter this hurdle. In the magnitude model, the mean probability of being a nonuser under baseline conditions was constant at just under 44.75%. The other two probabilities—being a user or a potential user—do change as alternative policies change. Under the baseline (actual) situation, the mean probability of being a user is just over 55.25%, while the mean probability of being a potential user is very small (6.0 × 10⁻⁵ percent). The mean expected number of reservoir fishing trips, conditional on being a user, is 14.61, while the unconditional estimate of mean trips is 8.11.

As water levels are raised under the alternative policies, the probability of being a user increases, while the probability of being a potential user falls. Empirically, the change was quite small: for the change from baseline scenario to the full pool scenario, the probabilities changed by only 1.9 × 10⁻⁵ percent. Additional water in August does not appear to draw anglers from a corner solution (no reservoir fishing) to an interior solution.

¹² This policy-scenario problem is the reason Cameron et al., and Cordell and Bergstrom found it necessary to use hypothetical valuation methods to augment their actual behavior models.
Table 4. Mean Willingness-to-Pay Calculations for Water Level Scenarios

<table>
<thead>
<tr>
<th>Water Level Magnitude Model</th>
<th>1996 “Standard” Drawdown</th>
<th>Full Pool through August 31</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Seasonal (March 1–August 31)</td>
<td>$0.28</td>
<td>$1.82</td>
</tr>
<tr>
<td>Willingness to Pay (WTP)</td>
<td>($0.22–$0.35)</td>
<td>($1.38–$2.33)</td>
</tr>
<tr>
<td>Mean ΔE(Trips)</td>
<td>0.052</td>
<td>0.334</td>
</tr>
</tbody>
</table>

a Denotes 95% confidence interval (calculated by Krinsky-Robb method using Hessian covariance matrix).

(making at least one trip), suggesting that August water levels are not a major hurdle for potential reservoir anglers over the six-month season. This makes some intuitive sense in that lakes are at full pool from roughly late May through July 31. If water levels were a “make-or-break” site characteristic, reservoir anglers would choose to fish during this portion of the season. The very small estimated probability of being at a corner may be more the result of behavioral data limitations than the absence of a water level hurdle. Indeed, Cameron et al. used monthly data when they found evidence that water levels did act as a site-quality hurdle. Whether an August hurdle exists remains an unresolved question.

Just because water levels were not a major hurdle during the six-month season, however, does not mean that levels were unimportant. Water levels had an impact on the estimated number of reservoir fishing trips. The mean number of fishing trips, conditional on being a reservoir user, is 14.73 for the 1996 scenario and 15.27 for the full pool scenario. For the full sample of anglers, the mean number of fishing trips under the 1996 scenario is 8.16, whereas the mean number of trips for the full pool scenario is 8.44. Thus, the full pool proposal put forth by advocacy groups within the study area would result in, on average, an additional one-third trip per season per angler (i.e., 8.44 – 8.11). Given that approximately 262,000 people in the study region engage in recreational fishing, this means that maintaining full pool through August 31 would approximately result in an additional 87,000 fishing trips.

Willingness to Pay for Alternative Policies

Willingness-to-pay (WTP) measures were calculated for each of the alternative policy scenarios for the linked site-choice/trips MNL/DH model (table 4). Parsons, Jakus, and Thomasi (p. 149) provide the formula for the welfare measure, noting that it is the difference between expected trips under each scenario divided by the coefficient of the inclusive value. This is conceptually equivalent to integrating under the demand curve for trips. For the 1996 “standard” policy, the seasonal (March 1 through August 31) WTP measure was $0.28, with a 95% confidence interval (CI) between $0.22 and $0.35. For the full pool scenario, the mean seasonal WTP was $1.82 (with a 95% CI of $1.38–$2.33).

13 A single-hurdle version of the model was also estimated, but the results did not qualitatively or quantitatively differ from the double-hurdle model (the model is available upon request from the authors). The MNL/DH was used as the estimating model because an important part of the policy question was whether water levels represent a hurdle. A reviewer has cautioned, however, against assigning much validity to such small probabilities.
With just under 262,000 anglers in the east Tennessee study region, the aggregate benefit of a full pool policy would be approximately $476,500 over the six-month season.

The estimated welfare change is similar to the findings reported in a recent study of anglers in Nevada, but is still relatively small in comparison to most of the past literature. Shaw et al. studied a Nevada lake that had been drained in 1992, killing all the fish. Their model found an aggregate benefit to anglers of $100,000 if the “average” minimum pool in 1992 had been maintained, rather than having the lake drained (a per trip measure could not be calculated). Cordell and Bergstrom estimated the aggregate benefit for a policy holding four TVA lakes in North Carolina at full pool for one additional month to be $5.1 million. The Cordell and Bergstrom estimate is about nine times as large as the estimate for the Tennessee lakes, but also includes benefits accruing to recreationists other than anglers (i.e., campers, hikers, picnickers, etc.). Fadali and Shaw estimated the benefit for keeping a volume of water sufficient to avoid fish kill at a remote Nevada lake with few substitutes. The per trip benefit was just under $30, with an aggregate benefit of $4.2 million.

The range of benefits for maintaining water levels in lakes is clearly quite wide; the estimate from this study is within this range, though at the lower end of the scale. Our estimate of aggregate benefits, however, may be somewhat understated because TVA does not maintain a “standard” policy for post-August 1 drawdowns. An established, predictable drawdown policy might yield surplus gains in excess of this amount if anglers, especially out-of-state anglers with little access to lake-level information, could rely upon a full pool until August 31.

Conclusions

The MNL/DH models indicate that reservoir water levels in the month of August are important to anglers. Water levels may not represent a barrier to participation during the full six-month fishing season because anglers can fish reservoirs before the August drawdown begins. Low August water levels may be a hurdle to participation during the month of August, but the available data do not allow us to test that hypothesis. Even in the absence of hard evidence for a hurdle, however, the models suggest that water levels do affect the number of trips that anglers make during the season. When water levels are high during the month of August, anglers take more trips for reservoir fishing relative to when water levels are low. Assuming the August full pool scenario advocated by local lake user groups is adopted, east Tennessee anglers would make an extra 87,000 trips per season. The aggregate consumer surplus of this policy is approximately $476,500.

Economic development is a primary goal of the Tennessee Valley Authority, and development could be stimulated by the additional 87,000 fishing trips that a full pool policy would spur. But a water management agency such as TVA is often faced with multiple, and sometimes conflicting, objectives. TVA, for example, is also responsible for providing flood control, downstream navigation, and hydroelectric power. A full pool policy can stimulate economic development, but may also engender costs associated with increased risk of flooding, increased risk of barge accidents if downstream channels are shallower, and decreased power generation. Future research would evaluate the full pool policy against costs of not meeting these additional objectives.

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References


