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Effects of Reservoir Levels on Arizona National Recreation Area Visitation, Visitor Spending, and Local Economies

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Research Impact Statement: Falling reservoir levels at Lakes Mead and Powell are associated with fewer recreation visits. Policies to avoid Colorado River Basin shortage declarations benefit recreationists and local economies.

ABSTRACT: This study estimates the effects of reservoir levels on demand for recreation visits to Lake Powell (Glen Canyon National Recreation Area) and Lake Mead National Recreation Area, correlating reservoir levels with overnight and total recreation visits. We also consider effects of closures of recreation access points (such as launch ramps or marinas) when lake levels fall below critical thresholds. Our overall results are similar to past studies, but find that the access point closures are a more robust predictor of visits than simple elevation measures. Policies that manage the Colorado River, including those that seek to maintain reservoir levels above critical levels with the primary goal of preventing water delivery cutbacks, also affect recreation demand and the economies of nearby communities. Our analysis maps changes in visits (from changing elevations) to changes in visitor spending, recreationist user benefits, and regional economic indicators such as value added and employment. Such indicators could be used in future benefit-cost or economic impact analyses of Colorado River water management policies.

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KEYWORDS: Outdoor recreation; drought; economic impact; Colorado River, national parks

INTRODUCTION

The Colorado River and its tributaries supply water to an estimated 40 million people in the United States, irrigate roughly 5.5 million acres of crops and pasture, and serve to generate hydropower for use across the West (USBR, 2012). Beyond these uses, the river also provides outdoor recreation opportunities along its 1,450 mile course from its headwaters to the Sea of Cortez. Two of the largest reservoirs in the United States, Lake Mead and Lake Powell, are located on the mainstem of the Colorado River. Lake Mead (created by Hoover Dam) situated along the Arizona-Nevada border is near the Las Vegas metropolitan area, while Lake Powell (created by Glen Canyon Dam) is located in Utah and Arizona (Figure 1). Formally designated as National Recreation Areas (NRAs) and managed by the National Park Service (NPS), Lake Mead NRA and Glen Canyon NRA (Lake Powell) ranked 6th and 19th nationally in recreation visits among NPS sites in 2019 (NPS, 2020). For context, Grand Canyon National Park ranked 9th.

[INSTER FIGURE 1]

The lakes serve as important drivers of tourism in nearby communities and, in 2018, total visitor spending within the local gateway communities surrounding Lakes Mead and Powell was estimated at $411 million and $336 million (Cullinane Thomas, et al., 2019). Because the reservoirs drive tourism-based economic activity in nearby communities, these areas are vulnerable to changes in factors that influence outdoor recreation demand, including climate change and variability (Thomas, et al., 2013). Sustained drought, a climatic anomaly, can impact water supplies in rivers, streams, and reservoirs. Past studies have demonstrated sensitivity of water-based recreation visitors to water levels (Ward and Fiore, 1987; English, et al., 1991; Loomis & Crespi, 1999; Eiswerth, et al., 2000; Hutt, et al., 2013; Neher, et al., 2013a; Boyer, et al., 2017). Policies surrounding the management of these two reservoirs, and the Colorado River Basin in general, have strong implications for the economic co-benefits of recreation to gateway communities and to recreation users alike.

This study estimates the effects of reservoir levels on demand for recreation visits to Lake Powell and Lake Mead, correlating reservoir levels with overnight and total recreation visits. In addition to examining reservoir surface elevations as a key explanatory variable for recreation visits, we also consider closures of access points (such as launch ramps or marinas) when lake elevations fall below critical thresholds. The estimated effects of reservoir level and recreation site closures on visitation demand are used to estimate the regional economic impacts of changes in visitation and visitor spending under different reservoir elevation scenarios, as well as changes in recreation visitor consumer surplus. Though the study does not directly consider long-term drought as measured by precipitation deficits in evaluating impacts, drought is a key factor influencing reservoir levels.

Under Intergovernmental Panel on Climate Change (IPCC) climate projections, the U.S. Southwest is expected to see reduced precipitation, less mountain snowpack, and reductions in runoff and streamflow by the end of the twenty-first century (Garfin, et al, 2013). Colorado River Basin water supplies are largely dependent on winter precipitation in the Upper Basin (Balling & Goodrich, 2007), and recent decreasing trends in snow water equivalent in the Basin have been detected (Miller & Piechota, 2011). Basin-wide drought, coupled with increasing temperatures, have been driving declines in Colorado River flow in recent years (Udall & Overpeck, 2017). These factors influencing water supply, along with increasing water demand in Colorado River Basin states and structural over-allocation of water supplies (Woodhouse, et al., 2006), are expected to result in declining reservoir levels for Lakes Mead and Powell (Kirk, et al., 2017).

A number of studies have considered the effects of reservoir levels on recreational use. Neher, et al. (2013a) model the influence of water levels on monthly recreation visits to Lakes Mead and Powell from 1996 to 2011 and find reservoir volume to be a positive and statistically significant predictor of visitation to both reservoirs. Loomis & Crespi (1999) estimate the effects of temperature and lake surface area on monthly visitation for nine reservoirs in California. They find positive effects of both temperature and lake surface area on visitation. Other studies have estimated changes in net economic benefits to anglers as a result of reservoir draw-downs (Jakus, et al., 2000; Husar, et al., 1999; Hutt, et al., 2013).

Beyond reservoir levels, other environmental or climate-related factors, such as temperature and precipitation, influence recreation demand. Temperature and precipitation influence outdoor recreation through their effects on individual demand for recreation, as well as through their effects on natural resources required for recreation (Loomis & Crespi, 1999). Studies have found visitation to be negatively associated with precipitation (Hewer & Gough, 2019; Hewer, et al., 2015). The relationship between visitation and temperature appears to follow in inverted "U" pattern, increasing with temperature at first, but then declining beyond a threshold point (Buckley and Foushee, 2011; Frisvold, et al., 2011; Fisichelli, et al, 2015; Richardson & Loomis, 2004; Loomis and Richardson, 2006). As an alternative to controlling for temperature, other studies include monthly dummy variables, which capture the effects of both climatic and institutional seasonality (Neher, et al., 2013a; Bergstrom, et al., 2020).

A larger literature considers influences on park visitation demand more generally. Key determinants of demand include travel cost, population of tourist origin regions, park attributes, income, and any barriers to travel such as closures or travel restrictions. Travel cost is commonly captured using regional gasoline prices (Bergstrom, et al., 2020; McIntosh & Wilmot, 2011; Frisvold, et al., 2011; Kim & Jakus, 2019). Population of tourist origin countries or regions is commonly included as a key determinant of tourism demand for purposes of forecasting (Ghalehkhondabi, et al, 2019). Poudyal, et al. (2013) find population is one of the most important predictors of aggregate national park visitation. Studies have found mixed results on the effects of income on demand for travel to national parks, with some finding national park visits increasing with income or savings (Bergstrom, et al., 2020; Poudyal, et al., Tarrant, 2013), while McIntosh & Wilmot (2011) found it to be an inferior good. Finally, studies control for barriers to park visitation, such as post- September 11, 2001 disruptions to domestic and international travel (McIntosh & Wilmot, 2011; Stevens, et al., 2014; Frisvold, et al., 2011; Bergstrom, et al., 2020) or national park closures (Gabe, 2016).

ECONOMETRIC SPECIFICATION

Following the examples of Frisvold, et al. (2011) and Neher, et al. (2013a), we model visitation demand to each reservoir in month t as:

$$\ln y_t = \alpha + \beta X_t + \gamma W_t + \theta \ln y_{t-12} + \varepsilon_t \qquad (1)$$

where X_t is a vector of climate and drought variables pertaining to time t, including our main explanatory variables of interest, reservoir levels and the number of access points closed due to low lake elevation, and W_t is a vector of variables capturing regional or national economic and demographic trends. A Breusch-Godfrey Lagrange multiplier test (Breusch, 1978; Godfrey,

1978) indicated the presence of autocorrelation in the monthly data. We correct for seasonal autocorrelation by including a 12-month lag of the dependent variable in the model. Models are estimated using linear regression, with each reservoir, visitor segment (overnight and total recreation), and lake level variable (elevation or number of access points closed) analyzed separately, for a total of eight models.

DATA

This analysis evaluates the effects of reservoir levels on total recreation visits and overnight recreation visits (a subset of total recreation visits) to Lakes Mead and Powell. Visits to Lakes Mead and Powell have fluctuated over time, peaking in 1992 at 12.6 million annual recreation visitors combined, and nearly reaching that level again in 2017 at 12.5 million annual recreation visitors combined (Figure 2).

[INSERT FIGURE 2]

Source: National Park Service (2020)

Monthly recreation visitation to both reservoirs exhibits a strong seasonal trend, with visits peaking in summer months between June and August, and typically reaching their lowest levels in December or January (Figure 3). While visitation has seen increases and decreases over the 40-year study period, those trends have not persisted long-term and overall, visitation has only seen small increases for both reservoirs.

Reservoir surface elevations of Lakes Mead and Powell also exhibit seasonal fluctuations. Lake Mead typically reaches its highest levels in February or March. Lake Powell reaches its highest elevations in summer months, often in August. Over the study period, both reservoirs have experienced a decline in elevation, despite seasonal and annual variations (Figure 4). During the sample period, Lake Powell achieved a minimum elevation of 3,556 feet in March of 2005 and a maximum of 3,707 feet in July of 1983. Lake Mead achieved a minimum elevation of 1,071 feet in June of 2016 and a maximum of 1,225 feet in July of 1983 (Figure 4).

[INSERT FIGURE 3]

Source: National Park Service (2020)

[INSERT FIGURE 4]

Source: USBR

These declines in elevation affect water access to marinas, boat ramps, navigational passages, and other infrastructure. In addition to reservoir elevation, we incorporate critical reservoir elevations at which specific recreation-based infrastructure such as marinas, launch ramps, and navigational access would become inoperable at Lakes Mead and Powell (Tables 1 and 2).

[INSERT TABLE 1]

[INSERT TABLE 2]

The number of inaccessible recreation access points in a given month is summed, for a count of inaccessible recreation access points. The critical reservoir elevation levels are drawn from the *Final Environmental Impact Statement for the Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lakes Powell and Mead* (hereafter *Interim Guidelines*) (USBR, 2007).

For Lake Powell, water access to Rainbow Bridge (Access Level 1) is restricted in over half of the sample period (Table 3). Other launch ramps and marinas are closed due to low lake elevations during the sample period (Access Levels 2 – 5). Three of eight critical levels (Access Levels 6, 7, and 8) remain accessible for the entire study period, and therefore are excluded from the analysis.

[INSERT TABLE 3]

Lake Powell's elevation fluctuates seasonally, typically peaking mid-summer and reaching its lowest levels in spring. Starting around 2001, lake levels began to decline and since that time have almost exclusively remained at levels where recreational infrastructure is impacted by closures (Figure 5).

[INSERT FIGURE 5]

Source: USBR

For Lake Mead, four critical access elevations are inaccessible during portions of the study period, the most common of which was access to Pearce Bay Launch Ramp, for nearly 45% of the study period (Table 4). Two of six access elevations (Access Levels 5 and 6) remain accessible for the entire study period, and therefore are excluded from the analysis. Lake Mead's elevation also fluctuates seasonally, with peak levels typically occurring in early winter and seasonal lows occurring mid-summer (Figure 6).

[INSERT TABLE 4]

Consistent with outdoor recreation and travel demand models, we control for factors influencing demand for recreation travel (Table 5). This includes travel costs (captured by regional gasoline price), income (regional unemployment rate), population, weather (1-month Standardized Precipitation Index and average monthly temperature and its square), and institutional seasonality (quarterly dummy variables). A variable calculated as the population of top visitor origin

[INSERT FIGURE 6]

Source: USBR

states weighted by their share of total visitation was constructed to provide a relevant visitor population time-series. Glen Canyon visitor origin shares are based off of a 2016 visitor study using summer domestic visitor shares by state (Le & Strawn, 2018). Lake Mead visitors by origin are based on reported top states of origin (NPS, 2020b). Finally, an indicator variable controlling for post-September 11, 2001 travel impacts was included (beginning in September 2001 through December 2002), as was an indicator variable for months affected by federal government shutdowns.

[INSERT TABLE 5]

Monthly national park visitation data by visit type (total recreation and overnight) were retrieved from the Integrated Resource Management Applications (IRMA) Portal (National Park Service, 2020a) for Glen Canyon NRA and Lake Mead NRA from January 1979 through December of 2018, with a total of 480 park-month observations for each park. The variable 'total recreation visits' is inclusive of overnight visits. Because estimation procedures for overnight visitors (predominantly lodging-based counts) and total recreation visitors (predominantly traffic-based counts) differ, a reliable estimate of day-use visitors cannot be obtained by subtracting overnight visitors from total recreation visitors. Average monthly reservoir elevation data were retrieved from the Bureau of Reclamation (USBR) for both Lakes Powell and Mead.

[INSERT TABLE 6]

RESULTS

Models were run using least squares regression with robust standard errors to address heteroskedastic errors detected in all but two models, using a Breusch-Pagan test. Where the null hypothesis of no heteroscedasticity could not be rejected, ordinary least squares estimates were applied. Additionally, variance inflation factors computed for all models identified potential collinearity issues between explanatory variables, particularly for Lake Mead models where there was a strong negative correlation between population and reservoir levels. Nevertheless, population was kept in the models due to its importance as a driver of reservoir visitation demand. Furthermore, estimated coefficients were relatively stable across models, and in many cases, across reservoirs, suggesting model estimates are robust.

Total Recreation Visitors

Logged reservoir elevation for Lake Powell was estimated to have a positive, statistically significant effect on logged total monthly recreation visits (Table 7). To account for seasonal effects on visitations, a quarterly dummy (spring, summer, and fall) was included in regressions. Average monthly temperature and its square were included in the model to capture the effect of temperature on visitation. Temperature was positive and statistically significant in all models, while temperature squared was positive but only significant in two models. The negative effect of high temperatures on visits observed in other studies may be attenuated in this case because the study examines water-based recreation which is most popular during summer months. SPI was negative in all models, suggesting above-average precipitation deters recreation visits, however the estimate was not statistically significant. Logged recreation visitation was negatively correlated with the unemployment rate, and both the post-September 11th dummy and the federal government shutdown dummy were negative and statistically significant in all models. The recreation access point model for total recreation visits to Lake Powell had similar results to the logged reservoir elevation model. The number of recreation access points closed was negative and statistically significant at the 10% level. All other coefficients were similar in sign, magnitude, and statistical significance as the logged reservoir elevation model (Table 7).

[INSERT TABLE 7]

For Lake Mead, logged reservoir elevation was estimated to have a positive, but not statistically significant effect on total monthly recreation visitors. These results mirror those of Wu (2019) who conducted a replication study of Neher et al. (2013a). Using the same data sources and model specification as Neher et al. (2013a), Wu was able to replicate their results for the years of the original study, 1996 to 2011. The main results of the original study – the strong positive association between reservoir volumes and visits – was not robust when extending the period of analysis from 1979 to 2017. A significant positive relationship between volume and visits was not found for Lake Mead for 1979-1995, 1996-2017, or the entire period 1979-2017. In the present analysis, however, the model using the number of recreation access points closed was estimated to have a negative and statistically significant effect on visitation. Again, estimated coefficients are similar in sign and magnitude across models and across reservoirs (Table 7).

[INSERT TABLE 8]

Overnight Visitors

For Lake Powell, logged reservoir elevation was estimated as having a positive, but not statistically significant effect on overnight visitors. The number of recreation access points closed, however, was estimated to have a negative and statistically significant effect on visitation (Table 8). For Lake Mead, logged reservoir elevation was estimated to be positive and statistically significant at the 10% level. Meanwhile, the number of recreation access points closed was again negative, and significant at the 5% level. SPI is negative across all models, suggesting that overnight visitation is deterred during rainier-than-normal months, thought the estimates were not statistically significant. Counterintuitively, the log of population was estimated to have a negative and statistically significant effect across all models and reservoirs. Compared with Lake Powell, monthly visits to Lake Mead do not show as strong a correlation with reservoir levels. Lake Mead is located close to a major metro area (Las Vegas, Nevada), therefore local visitation may be relatively insensitive to lake levels, particularly considering the limited number of options for water-based outdoor recreation in close proximity. As of 2018, overnight visits accounted for about 20% of recreation visits to Lake Powell, while for Lake Mead they accounted for less than 10%.

RESERVOIR ELEVATION SCENARIOS & ESTIMATED EFFECTS ON VISITATION

To model the effects of reservoir levels on visitation to Lake Mead and Lake Powell, we consider several lake elevation scenarios and model the effects as if they had occurred in 2018. Scenarios are based on a series of key reservoir elevations that trigger shortage declarations and water delivery cutbacks under the Drought Contingency Plan. Under the Drought Contingency Plan Authorization Act (P.L. 116-14) and the drought contingency plans developed by the Basin States and U.S. Bureau of Reclamation (Stern and Sheikh, 2020), Lower Basin states face water delivery cutbacks based on specific reservoir elevations levels at Lake Mead, while the U.S. Bureau of Reclamation is also required to implement additional conservation efforts and coordinate reservoir operations to prevent Lake Powell from falling below the minimum power pool level.

Both Lake Mead and Lake Powell levels are based upon target elevations under the Drought Contingency Plan (Arizona Water Banking Authority, 2020; Bureau of Reclamation, 2019a) and assume a constant monthly lake elevation equal to the respective Drought Contingency Plan level. A baseline scenario uses actual 2018 average monthly elevations for purposes of comparison. All visitation estimates are modeled using the critical elevation models and assuming values from 2018, the last year of data in the regression analysis for all explanatory variables, except reservoir levels which vary by scenario. Tables 9 and 10 present estimated visitation levels (total recreation visits and overnight recreation visits) in 2018 at different counterfactual elevation scenarios for Lakes Powell and Mead.

[INSERT TABLE 9]

[INSERT TABLE 10]

A number of modeled elevations fall outside the range of the sample. Over the sample period, Lake Powell's minimum monthly elevation is 3,556 feet and Lake Mead's is 1,072 feet. Lake Mead's DCP Tier 2a Threshold and lower elevations are not attained during the sample period, nor is Lake Powell's DCP Target elevation of 3,525 feet and below. Estimates for these elevations are out of sample and therefore should be interpreted with some caution.

Neher, et al. (2013a) estimate the marginal impacts on visitation of a 100,000 acre-foot change in reservoir storage for both reservoirs (a 10.3 inch drop in surface levels at Lake Powell and a 9.3 inch drop at Lake Mead). For Lake Powell, over the course of a year, they find an additional 100,000 acre-feet of storage (again, a roughly 1-foot elevation change) was estimated to result in 5,280 more visitors and for Lake Mead, an additional 13,490 visitors. As a percent of 2011 annual visits, these changes represent a 0.23% increase for Lake Powell and a 0.21% increase for Lake Mead. By comparison, estimates from this study rely on the critical elevation model to estimate changes in visits based on reservoir surface elevations, therefore marginal estimates from Neher, et al (2013a) are not directly comparable. According to this study's estimates, a decline from 3,588 feet to 3,550 feet (38-foot drop) for Lake Powell would be associated with a 5.2% decrease in visits, and a decline from 1,090 feet to 1,075 feet (15-foot drop) for Lake Mead would be associated with a 2.4% decrease in visits. If the marginal estimates from Neher, et al (2013a) were applied to these larger drops in elevation, it would result in a 10.2% change in 2011 visits for Lake Powell and a 4.1% change in 2011 visits for Lake Mead.

Frisvold, et al. (2011) also estimate the change in visitation that would result from reservoir surface elevation declines. They estimate a decline in Lake Powell's elevation from 3,608 feet to 3,490 feet would result in 6.8% fewer annual visits and a decline to 3,370 feet would result in 16.2% fewer visits. For Lake Mead, they estimate a decline from 1,145 feet to 1,075 feet would result in 10.5% fewer visits and a decline to 1,050 feet would result in 14.1% fewer visits. On a per-foot of reservoir elevation basis, the estimates from this study are similar in magnitude to those by Frisvold, et al. (2011).

ECONOMIC IMPACTS OF DECLINING RESERVOIR LEVELS

Past studies have applied three different approaches to measure of the economic impacts of changing reservoir levels: visitor spending changes, economic impact analysis, and consumer surplus (welfare) analysis. Each approach measures different types of economic outcomes and has different data requirements. Analyzing visitor spending is the most basic. Here, spending profiles are developed for different types of visits to a recreation site. For example, day hikers may spend less at gateway communities to the site than those making overnight stays. These latter stays can involve more spending for lodging, restaurants, etc. These spending patterns are usually developed based on site-specific visitor surveys. The next step is to develop estimates of how the number of (different types of) visits changes with reservoir levels.

Economic impact analysis takes visitor spending as a starting point. That initial visitor spending (the direct effect) creates additional demand for goods and services in a local economy. This additional demand is divided into two types of multiplier effects. The first are indirect effects. Goods and services supplied as part of visitor spending require inputs of goods and services themselves. Those inputs, in turn, require inputs. So, initial visitor spending creates repeated, diminishing rounds of additional spending. Second, induced effects occur when people employed by tourism-related businesses spend their salaries, wages, and business profits on consumption of local goods and services. These multiplier effects account for additional goods and services that are locally supplied and not those "imported" from outside the region. Economic impact analyses make use of input-output models to capture linkages between businesses and between businesses and households. In addition to measuring both direct and multiplier effects on sales (output), such models also measure impacts on labor income (wages, salaries, and proprietors' income), value added (labor income, plus taxes, corporate profits, and other property income), and jobs. Value added is the local equivalent of gross domestic product, used to measure the size of the national economy. This additional information about jobs and tax revenues is often of interest to state and local officials. In economic impact analyses, changes in visits are translated into changes in visitor spending, which in-turn are introduced as "shocks" into an input-output model. The model then measures the cumulative effects of the subsequent rounds of economic activity in other industries generated by the original change in spending.

Consumer surplus (welfare) analysis measures the economic value of the benefit that recreationists get from visiting a site. Benefits are estimated based on non-market valuation techniques, such as contingent valuation or travel cost methods. Benefits are often measured in terms of the dollar value of economic benefit recreationists derive per trip. Changes in trips, resulting from changes in reservoir levels, may then be used estimate changes in recreationist benefits (consumer surplus).

In the original Severe Sustained Drought study, Booker and Colby (1995) focused on benefits to recreationists. Frisvold et al. (2011) considered both visitor spending and input-output effects of changes in reservoir levels of Lake Powell and Lake Mead. Hutt et al. (2013) examined the effects of changing reservoir levels in Mississippi on angler visits, expenditures, input-output impacts (total sales, jobs) and consumer surplus. In their *Interim Guidelines*, the U.S. Bureau of Reclamation (USBR, 2007) discussed qualitatively the effects of reservoir level reductions under different drought and policy response scenarios. While USBR reported quantitative economic impacts of drought for Lower Basin agriculture, they did not attempt to quantify impacts of declining reservoir levels.

To estimate the visitor spending changes, economic impacts, and consumer surplus changes associated with declining reservoir levels at Lakes Mead and Powell, we apply model results from this study, as well as estimates from previous studies. Changes in visitor spending and regional economic impacts are estimated using NPS visitor spending profiles and NPS regional economic impact multipliers for 2018 (Cullinane Thomas, et al., 2019); Cullinane Thomas, unpublished; National Park Service, 2020c). Changes in consumer surplus are estimated using benefit transfer and use value estimates for water-based recreation. Results from this study's regression analyses were used to create a range of estimated impacts for each park. We rely on the critical recreation access level models to estimate visitation under a series of Drought Contingency Plan-based scenarios.

Changes in Visitor Spending

Changes in visitor spending are estimated by applying existing visitor spending patterns to the estimated decreases in visitation that would result at different reservoir elevations. Tables 11 and 12 present the estimated changes in visitation resulting from reservoir elevations higher or lower than actual 2018 averages.

[INSERT TABLE 11]

We apply the method detailed by Cullinane Thomas, et al. (2019) to convert total recreation and overnight visit estimates to estimates of the number of party days or nights by visitor segment.

[INSERT TABLE 12]

An NPS pilot spending profile by lodging-based visitor segments is available for Glen Canyon NRA, including visitor shares by segment (Cullinane Thomas, et al., 2019). A recent visitor spending pattern is not available specifically for Lake Mead, therefore we apply the spending pattern for Glen Canyon NRA. The Glen Canyon NRA visitor spending pattern does not include spending estimates for local day visitors, nor for non-local day visitors. We use a generic spending profile available for local and non-local day visitors to National Recreation Areas (Cullinane Thomas, personal communication) and apply segment splits by visitor type from 2018 NPS visitation data accessed via the IRMA portal (National Park Service, 2020a). The third column in Tables 13 and 14 present the estimated changes in direct visitor spending.

Regional Economic Impacts

Regional economic impacts are estimated using changes in visitation, NPS visitor spending profiles, and NPS regional economic impact multipliers for 2018 (Cullinane Thomas, et al., 2019); Cullinane Thomas, unpublished; National Park Service, 2020c). Overnight visits are subtracted from total recreation visits for purposes of calculating economic impacts because overnight visits are a subset of recreation visitors and not taking the difference would lead to double-counting. We apply total spending (less rental car spending) by visitor segment, excluding local day visitors, and use multipliers derived from NPS estimated economic impacts of national parks in 2018 (National Park Service, 2020c). Local visitors are typically excluded in economic impact analyses to account for substitution of local spending from one activity to another, in other words, if local visitors did not spend their money on a visit to the park, they would have spent it on something else. Park economy multipliers used in this analysis consider the economic impacts of national parks to surrounding 'gateway' communities, and therefore the multipliers can be interpreted as regional multipliers, as opposed to state-level multipliers.

Tables 13 and 14 present the estimated regional economic impacts in 2018 from alternative reservoir elevation scenarios, including direct, indirect, and induced multiplier effects. Results are presented in terms of output (sales), value added (equivalent to gross domestic product), labor income (income of employees and business proprietor income), and jobs (full- and part-time employment).

[INSERT TABLE 13]

[INSERT TABLE 14]

The economic impacts of changes in reservoir elevation to gateway communities are estimated to be larger for Lake Powell compared with Lake Mead. Again, based on its proximity to the Las Vegas metropolitan area, visitation may be less sensitive to changes in reservoir elevations.

Changes in Recreation User Benefits

To estimate effect of drought on reservoir recreation benefits in the Colorado Basin, Booker and Colby (1995) obtained estimates of per-trip benefits from existing studies. Economic damages from falling reservoir levels were based on estimated losses from reductions in the number of trips taken. They assumed that lower levels did not affect benefits to those still making trips. Eiswerth, et al. (2000) maintained the same assumptions in their analysis of declining levels of Walker Lake in Nevada. Booker and Colby used estimates of benefits of $25.21 per day for Lake Powell and $34.96 per day for Mead in 1992 dollars. These are equivalent to $42 / trip for Lake Powell and $58.27 / trip for Lake Mead in 2019 dollars (using the GDP price deflator; 2019 is the most recent year with complete deflator data). Booker and Colby did not attempt to estimate relationships between reservoir elevations and visits directly. Rather, they relied on a formula based on earlier work of Ward and Fiore (1987) that examined visits to New Mexico reservoirs. That study used the square root of reservoir area as a variable to explain differences in visits at different reservoirs. Applying this square root formula and the projected reductions in reservoir levels, the original Severe Sustained Drought (SSD) study estimated economic losses from falling reservoir levels at Lakes Powell, Mead, and other reservoirs in the Colorado Basin (Booker, 1995). Booker (1995) found that under the SSD drought scenario that recreation benefits declined by 12% by year 16 of the multi-year drought, but benefits to Lake Powell boaters fell 49%.

Based on survey data from 1997, Douglas and Johnson (2004) estimated a travel cost model to estimate consumer surplus from visits to Lake Powell. They reported results from two regression specifications, with values ranging from $70.83 to $159.36 per trip in 1997 constant dollars. This corresponds to $106.88 and $240.42 per trip in 2019 dollars. These estimates and those of Booker and Colby (1995) are now quite dated. Yet, surprisingly, to our knowledge they are the only studies reporting consumer surplus benefits directly for visits to Lakes Mead and Powell.

To estimate the effects of changes in reservoir elevations on consumer surplus, we follow the approach of Booker and Colby (1995) and Eiswerth, et al. (2000) in that we assume that surplus changes come from changes in the number of visits, while "use benefits for each visitor are unchanged as reservoir level changes (p. 883) (Booker and Colby, 1995)." The first step in our analysis is to update the Booker and Colby (1995) and Douglas and Johnson (2004) benefit estimates for Lakes Powell and Mead to 2019 dollars. This implicitly assumes that real (inflation adjusted) values per trip have not change appreciably since these early studies.

Next, to supplement these estimates, we rely on outdoor recreation use values developed for benefit transfer based on three extensive literature reviews and statistical analyses (Kaval and Loomis, 2003; Kaval, 2006; Neher 2013b; Rosenberger, et al., 2017). We also made use of data from the USGS Benefit Transfer Toolkit, which in turn builds upon the Benefit Transfer and Use Estimating Model Toolkit developed at Colorado State University (Loomis and Richardson, 2007; Loomis et al., 2008).

The only direct measures of use values for Lakes Powell and Mead come from Booker and Colby (1995) for 1992 and from and Douglas and Johnson (2004) for 1997. Booker and Colby (1995) weighted use values by type of trip, assigning a 0.2 weight to fishing and 0.8 to other activities (Table 15). To consider more recent data, we make use of estimates for fishing and motor boating from the four above reports and from the USGS Toolkit. Kaval and Loomis (2003) and Kaval (2006) report these use values for National Park System sites in the Intermountain West. Rosenberger et al. (2017) report these values for Forest Service Region 4 (Lakes Mead and Powell are located in the southern extent of Region 4). Neher (2013b) report estimates for National Recreation Areas in the Intermountain West. Values are reported in terms of visits per person per day. National Park Service estimates of a "visit" to an NPS site (as used in the regression analysis above) are also reported in terms of entry and stay per person per day (Ziesler and Pettebone, 2018). These use values are weighted between fishing and motor boating and then converted to 2019 dollars for comparison with earlier estimates of Booker and Colby and Douglas and Johnson (2004) (Table 15).

The use value estimates developed for benefit transfer by Kaval and Loomis (2003), and Rosenberger et al. (2017) suggest use values in the range of $67 - $75 per person per day for water-based activities in the regions that include Lakes Mead and Powell. Earlier estimates from Booker and Colby for the two reservoirs suggest lower estimates, while estimates from Douglas and Johnson (2004) for Lake Powell are higher, in the $106 -$240 range. More recent estimates (from 2011) by Neher et al. (2013b) estimated a value of $97 per person per day ($112 in 2019 constant dollars). The USGS Toolkit reports average values for fishing $78.83 ($2016) and $34.97 ($2016) for motor boating in the Intermountain West (Table 15). Weighting these as above places values at $46.46, in between the two estimates by Booker and Colby (1995). These average values from the Toolkit, though are based on many estimates that are older (often much older) than those of Booker and Colby (1995). The number of studies for fishing and boatin in the Intermountain West in the Toolkit Taking more recent than Booker and Colby (1995) is relatively small (Aiken, 2009; Aiken. and la Rouche. 2003; Bhat, et al., 1998; Englin and Cameron, 1993; Fadali, and Shaw, 1998; Harris, 2014; Shonkwiler, 1995; Williams, 1994). Table 15 also reports the average from these more recent studies reported in the Toolkit. Weighting these values 0.2 for fishing and 0.8 for motor boating yields a value of $75.14, which is quite close to (essentially the same as) estimates based on Rosenberger et al.'s study, $75.06.

[INSERT TABLE 15]

Table 16 shows total reductions in user benefits (user losses) as reservoir elevations fall below their 2018 baseline levels. The table also compares these user losses with estimated regional reductions in visitor spending and value added, including multiplier effects. For Lake Mead NRA the Low estimate of losses is based on the $58.33 per trip benefit derived from Booker and Colby (1995) (Table 15). The Middle estimate is based on the $75.06 per trip benefit derived from Rosenberger et al. (2017) (Table 15), while the High estimate is based on the $112 value from Neher et al., 2013b. For Glen Canyon NRA (Lake Powell), the Low estimate is derived from Booker and Colby (1995), the Middle estimate from Rosenberger et al. (2017), and the High estimate is based on Neher et al., 2013b), while the Very High of a $240.42 per trip benefit is based on Douglas and Johnson (2014) (Table 15).

[INSERT TABLE 16]

Table 16 illustrates different types of economic losses from falling reservoir levels. Visitor spending captures lower expenditures in the region. Spending, however, does not account for how much direct local spending “leaks out” of the local economy, because goods and materials to produce them are often “imported” from outside the region. Value added accounts for multiplier effects of initial spending on other sectors of the economy, but also accounts for this leakage. Value added captures proprietors’ income, wages and salaries, other property income (e.g. corporate profits) and tax revenues. As such, it represents economic impacts on the residents, businesses, and government of the local economy. The benefits that recreationist derive are the user benefits.

The recreation user benefits presented here are meant to be illustrative and are by no means definitive. For these specific recreation sites, the estimates are dated. While we have supplemented these older estimates with reference estimates that have been used extensively in National Forest Plans and Environmental Impact Statements, we echo Loomis’ (2015) caution, “As policy makers … become aware of the option of benefit transfer, they may over-emphasize its use, leading to the loss of additional original valuation studies.” Given the importance of Lakes Mead and Powell to water-based recreation in the Colorado Basin, more up-to-date and direct measures of these recreation benefits would be welcome.

DISCUSSION & CONCLUSIONS

Monthly recreation visits and overnight visits to Lakes Powell and Mead exhibit positive correlations with their respective surface elevations. Furthermore, when reservoir elevations fall and access to recreational infrastructure sites such as boat-launch ramps and marinas is cut off, recreation and overnight visitation declines. Surface elevations of both reservoirs have been declining gradually over time, and the likelihood of the reservoirs falling to levels that trigger cutbacks to Lower Basin states in response to shortage conditions is estimated as high as 77% in the next five years (USBR, 2020). Further declines in surface elevations may have negative impacts to recreation visitation, including overnight visits, with economic implications for local gateway communities.

Reservoir management must balance the many functions reservoirs serve, including water storage and delivery, flood control, electricity generation, ecosystem services, and provision of recreation opportunities. Lakes Mead and Powell are managed to provide reliable water supplies to tribal, municipal, industrial, and agricultural users throughout the Lower Basin states, serving jointly as a buffer against natural river flow variability by storing the equivalent of years of natural river flows. Despite their robust storage capacity, they are nonetheless susceptible to drought and over-allocation of water supplies. In recent years, cooperative efforts by basin states and Mexico have aimed to maintain reservoir levels above critical levels that trigger delivery cutbacks. These have included system-wide conservation efforts (Bureau of Reclamation, 2019), and bi-national agreements for storage sharing and provision of water for the environment (IBWC, 2012; IBWC, 2017).

Both public and private entities have specific objectives to maintain the reservoir levels at Lakes Mead and Powell above defined threshold levels. The USBR *Interim Guidelines* created the Intentionally Created Surplus program allowing Lower Basin states (California, Nevada and Arizona) to store water in Lake Mead by creating a like amount of water in their state to be used instead (USBR, 2007). In 2014, USBR and major basin water supply agencies (Central Arizona Water Conservation District, Denver Water Southern, Metropolitan Water District of Southern California, and Nevada Water Authority) implemented a memorandum of understanding to fund voluntary conservation projects aimed at increasing elevations at Lake Mead. Federal participation in these projects was authorized through the Energy and Water Development and Related Agencies Appropriations Act of 2015 and the Energy and Water Development and Related Agencies Appropriations Act of 2019 (Stern and Sheikh, 2020). Further, local funding agencies, the Environmental Defense Fund, and the Walton Family Foundation have joined the federal government in funding 16 Pilot Program projects in the Lower Basin to maintain Lake Mead elevations above the 1,075-foot threshold (USBR, 2019) and The Nature Conservancy has been involved in projects to achieve voluntary reductions in irrigation and maintain the saved water at Lake Powell (TNC, 2018; 2021). Perhaps the most substantial effort to maintain reservoir levels came in 2019 when the Basin States and USBR transmitted to Congress drought contingency plans (DCPs) to address potential water supply shortages.

The goal of these various measures that target elevations at Lakes Powell and Mead is to manage water supplies, not necessarily to maintain recreation benefits or local recreation-linked economic activity. Yet, these measures do generate economic co-benefits to the gateway communities to these lakes and to recreationists. Previous analyses of the economic implications of reservoir management in the USBR *Interim Guidelines* (USBR, 2007) discussed qualitatively the implications of those management decisions for recreation, but did not quantify their economic consequences. Our analysis maps changes in visits (from changing elevations) to changes in visitor spending, recreationist user benefits, and regional economic indicators such as value added and employment. Such indicators could be used in future benefit-cost or economic impact analyses of Colorado River water management policies.

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Tables

Table 1. Lake Powell Access Levels Used in Analysis

Access Level	**Elevation**	**Description**
1	3,650 ft	Water access to Rainbow Bridge closed
2	3,626 ft	Navigational detour required at Wahweap Marina and at Gregory Butte
3	3,620 ft	Hite Marina, Hite Public Launch Ramp, and Castle Rock Cut closed

4	3,588 ft	Antelope Point Public Launch Ramp is closed
5	3,560 ft	Wahweap and Stateline Public Launch Ramps, the Bullfrog Low Water Alternative Launch Ramp, and the Halls Crossing Public Launch Ramps are closed
6	3,555 ft	Wahweap, Antelope Point, Bullfrog, and Halls Crossing marinas are closed
7	3,550 ft	Operation of the John Atlantic Burr Ferry ceases
8	3,490 ft	Minimum power pool for efficient electrical generation at the Glen Canyon Power Plant

Source: USBR (2007)

Table 2. Lake Mead Access Levels Used in Analysis

Access Level	**Elevation**	**Description**
1	1,175 ft	Pearce Bay Launch Ramp is closed and whitewater boaters must paddle an additional 16 miles to South Cove
2	1,170 ft	Minimum elevation needed to maintain navigation between Grand Wash and Pearce Ferry
3	1,125 ft	Overton Beach Marina and South Cove Ramp are closed
4	1,080 ft	Operations of the Lake Mead Marina Public Launch Ramp, Hemenway Public Launch Ramp, and Temple Bar Public Launch Ramp could potentially be affected
5	1,050 ft	Minimum elevation needed for efficient power generation at the Hoover Powerplant, the minimum elevation for operation of the upper intake of SNWA, and the minimum elevation for the Echo Bay Boat Launch
6	1,000 ft	Minimum elevation needed by SNWA, to pump water from Lake Mead through its lower intake

Source: USBR (2007)

Table 3. Proportion of Study Period When Lake Powell Is At or Below Each Access Elevation Level

Access Level	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Mean Proportion	0.513	0.358	0.315	0.050	0.004	0	0	0

Table 4. Percent of Study Period when Lake Mead Is At or Below Each Access Elevation Level

Access Level	**1**	**2**	**3**	**4**	**5**	**6**
Mean Proportion	0.448	0.419	0.285	0.054	0	0

Table 5. Data Sources for Analysis

Variable	**Source**	**Periodicity**
National Park Service System visitors by type and park unit	National Park Service IRMA System	Monthly 1979 – 2018
Reservoir elevations	Bureau of Reclamation	Monthly 1979 – 2018
Gas price, all types, urban west	Federal Reserve Bank of St. Louis FRED Database	Monthly 1979 – 2018
State populations	Bureau of Labor Statistics	Monthly 1979 – 2018
Regional unemployment rate	Federal Reserve Bank of St. Louis FRED Database	Monthly 1979 – 2018
Standard Precipitation Index (SPI), 1-month	West Wide Drought Tracker	Monthly 1979 – 2018
Average monthly temperature	NOAA Climate at a Glance	Monthly 1979 – 2018
Consumer Price Index	Bureau of Labor Statistics	Monthly 1979 – 2018

Table 6. Descriptive Statistics for Variables Used in Analysis

Variable	Mean	Std. Dev	Min	Max
Log Recreation Visitors Lake Powell	11.91	0.86	10.13	13.68
Log Overnight Visitors Lake Powell	10.96	1.58	7.24	13.21
Log Recreation Visitors Lake Mead	13.31	0.34	12.35	14.04
Log Overnight Visitors Lake Mead	11.48	0.40	10.35	12.25
Log Elevation Lake Powell	8.20	0.01	8.18	8.22
Log Elevation Lake Mead	7.06	0.04	6.98	7.11
Lake Powell Access Cut-Off Elevation Count	1.24	1.42	0	5
Lake Mead Access Cut-Off Elevation Count	1.21	1.44	0	4
1-Month SPI, US Climate Division 4207	0.03	0.92	-1.85	2.11

(Southeast Utah)				
1-Month SPI, Climate Division 2604 (Extreme Southern Nevada)	-0.05	0.96	-1.63	2.67
Average Monthly Temperature, US Climate Division 4207 (Southeast Utah)	52.88	16.71	19.7	82.1
Average Monthly Temperature, US Climate Division 2604 (Extreme Southern Nevada)	65.02	14.98	38.7	90.4
Log Western Region Gas Price	1.03	0.25	0.58	1.63
Log Relevant Population, Lake Powell	15.43	0.21	15.03	15.75
Log Relevant Population, Lake Mead	16.40	0.18	16.02	16.67
Regional Unemployment Rate (West)	6.70	1.75	4.1	11.0
Post 9-11 Dummy	0.03	0.18	0	1
Government Shutdown Dummy	0.01	0.08	0	1

Table 7. Total Recreation Visitor Model Results (dependent variable: log of total recreation visitors)

	Lake Powell		Lake Mead	
Log Reservoir Elevation	2.774* (1.443)	----	0.375 (0.367)	----
Recreation Access Points Closed	----	-0.018* (0.010)	----	-0.024** (0.010)
12-Month Lag Log Visitors	0.753*** (0.038)	0.747*** (0.038)	0.416*** (0.040)	0.400*** (0.041)
SPI (1-month)	-0.007 (0.011)	-0.006 (0.011)	-0.002 (0.007)	-0.001 (0.007)
Avg. Monthly Temperature	0.017** (0.009)	0.018** (0.009)	0.039*** (0.008)	0.039*** (0.008)
Avg. Monthly Temperature Squared	0.000 (0.000)	0.000 (0.000)	0.000*** (0.000)	0.000*** (0.000)
Spring Month Dummy	0.092 (0.059)	0.094 (0.059)	0.088*** (0.029)	0.092*** (0.029)
Summer Month Dummy	0.089 (0.069)	0.095 (0.069)	0.065* (0.036)	0.068* (0.036)
Fall Month Dummy	0.051 (0.062)	0.052 (0.062)	-0.023 (0.027)	-0.022 (0.027)
Log Population	0.108 (0.085)	0.091 (0.083)	0.313*** (0.083)	0.398*** (0.084)
Unemployment Rate, West	-0.010 (0.006)	-0.011* (0.006)	-0.001 (0.004)	0.000 (0.004)
Log Gas Price, West	-0.091** (0.045)	-0.094** (0.044)	-0.372*** (0.037)	-0.351*** (0.037)
Post 9-11 Dummy	-0.179***	-0.186***	-0.177***	-0.173***

	(0.025)	(0.025)	(0.031)	(0.031)
Fed. Gov't Shutdown Dummy	-0.406*** (0.105)	-0.401*** (0.108)	-0.274* (0.147)	-0.279* (0.147)
Constant	-22.061* (12.787)	1.037 (1.326)	-1.181 (3.758)	0.272 (1.230)
R^2	0.9443	0.9443	0.8624	0.8636

Statistically significant at the: * 10%; ** 5% level; ***1% level

Table 8. Overnight Visitor Model Results (dependent variable: log of overnight visitors)

	Lake Powell		**Lake Mead**	
Log Reservoir Elevation	2.744 (2.147)	----	0.758* (0.429)	----
Recreation Access Points Closed	----	-0.031** (0.014)	----	-0.025** (0.012)
12-Month Lag Log Visitors	0.683*** (0.041)	0.674 (0.040)	0.703*** (0.033)	0.699*** (0.033)
SPI (1-month)	-0.020 (0.018)	-0.017 (0.018)	-0.009 (0.006)	-0.009 (0.006)
Avg. Monthly Temperature	0.029** (0.014)	0.030** (0.014)	0.026*** (0.008)	0.027*** (0.008)

Avg. Monthly Temperature Squared	0.000 (0.000)	0.000 (0.000)	0.000*** (0.000)	0.000*** (0.000)
Spring Month Dummy	0.283*** (0.080)	0.292*** (0.079)	0.033 (0.030)	0.034 (0.030)
Summer Month Dummy	0.204** (0.097)	0.213** (0.098)	0.053 (0.039)	0.055 (0.039)
Fall Month Dummy	0.281*** (0.084)	0.287*** (0.084)	-0.006 (0.029)	-0.004 (0.029)
Log Population	-0.326** (0.128)	-0.290** (0.119)	-0.346*** (0.080)	-0.340*** (0.076)
Unemployment Rate, West	0.019* (0.010)	0.017* (0.010)	0.009 (0.004)	0.009** (0.004)
Log Gas Price, West	-0.141** (0.070)	-0.127* (0.070)	-0.144*** (0.034)	-0.134*** (0.036)
Post 9-11 Dummy	-0.161*** (0.052)	-0.169*** (0.053)	-0.022 (0.035)	-0.016 (0.035)
Fed. Gov't Shutdown Dummy	-0.105*** (0.039)	-0.100** (0.041)	-0.401*** (0.076)	-0.407*** (0.076)
Constant	-15.589 (19.027)	6.439*** (1.887)	2.913 (4.033)	8.230*** (1.350)
R^2	0.9653	0.9655	0.8972	0.8974

Statistically significant at the: * 10% level; ** 5% level; ***1% level

Table 9. Modeled Lake Powell Visitation in 2018 Based on Lake Elevation Scenarios (Recreation Access Elevations and Colorado River Drought Contingency Plan Thresholds)

Recreation Elevation	Recreation Access Points Closed	DCP Elevation	DCP Threshold	Recreation Visits	Overnight Visits
>3,650 ft	0	.	.	4,361,418	1,477,249
3,650 ft	1	.	.	4,284,447	1,432,309
3,626 ft	2	.	.	4,208,835	1,388,736
3,620 ft	3	.	.	4,134,558	1,346,488
3,588 ft	4	.	.	4,061,591	1,305,525
3,560 ft	5	.	.	3,989,912	1,265,809
*3,555 ft	6	.	.	3,919,498	1,227,301
*3,550 ft	7	.	.		
.	.	3,525 ft	DCP Target Elevation	3,850,327	1,189,965
*3,490 ft	8	3,490 ft	Minimum Power Pool Level	3,782,376	1,153,764
.	.	3,370 ft	Dead Pool		

* Lake elevation out of sample

Table 10. Modeled Lake Mead Visitation in 2018 Based on Lake Elevation Scenarios (Recreation Access Elevations and Colorado River Drought Contingency Plan Thresholds)

Recreation Elevation	Recreation Access Points Closed	DCP Elevation	DCP Threshold	Recreation Visits	Overnight Visits
>1,175 ft	0	.	.	10,085,363	882,993
1,175 ft	1	.	.	9,846,861	861,510
1,170 ft	2	.	.	9,614,000	840,548
1,125 ft	3	.	.	9,386,645	820,097
.	.	>1,090 ft	No DCP Cutbacks		
.	.	1,090 ft	DCP Tier 0 Threshold		

1,080 ft	4	.	.	9,164,667	800,143
.	.	1,075 ft	DCP Tier 1 Threshold		
*1,050 ft	5	1,050 ft	DCP Tier 2a Threshold	8,947,938	780,675
.	.	1,045 ft	DCP Tier 2b Threshold		
.	.	1,025 ft	DCP Tier 3 Threshold		
*1,000 ft	6	895 ft	Dead Pool	8,736,335	761,681

* Lake elevation out of sample

Table 11. Estimated Difference in Lake Powell 2018 Annual Visitation by Elevation Scenario Compared with Predicted 2018 Visits

Elevation	Description	Total Recreation	Overnight
3,603 ft	Predicted 2018 Visits	N.A.	N.A.
3,525 ft	DCP Target Elevation	-279,862	-156,036
3,490 ft	Minimum Power Pool Level	-347,813	-192,236
3,370 ft	Dead Pool	-347,813	-192,236

Table 12. Estimated Difference in Lake Mead 2018 Annual Visitation by Elevation Scenario Compared with Predicted 2018 Visits

Elevation	Description	Total Recreation	Overnight
1,090 ft	DCP Tier 0 Threshold	144,955	11,885
1,081 ft	Predicted 2018 Visits	N.A.	N.A.
1,075 ft	DCP Tier 1 Threshold	-77,023	-8,069

1,050 ft	DCP Tier 2a Threshold	-293,752	-27,537
1,045 ft	DCP Tier 2b Threshold	-293,752	-27,537
1,025 ft	DCP Tier 3 Threshold	-293,752	-27,537
895 ft	Dead Pool	-505,355	-46,531

Table 13. Estimated Regional Economic Impacts of Visitor Spending Effects of Lake Powell Elevation Scenarios. Including Multiplier Effects

Elevation	**Description**	**Change in Spending**	**Change in Output**	**Change in Value Added**	**Change in Labor Income**	**Change in Jobs**
3,603 ft	2018 Predicted (Elevation)	N/A	N/A	N/A	N/A	N/A
3,525 ft	DCP Target Elevation	-$33,965,331	-$39,915,461	-$23,056,757	-$13,222,513	-416
3,490 ft	Minimum Power Pool Level	-$42,104,085	-$49,479,983	-$28,581,605	-$16,390,885	-515
3,370 ft	Dead Pool	-$42,104,085	-$49,479,983	-$28,581,605	-$16,390,885	-515

Table 14. Estimated Economic Impacts of Visitor Spending Effects of Lake Mead Elevation Scenarios, Including Multiplier Effects

Elevation	**Description**	**Change in Spending**	**Change in Output**	**Change in Value Added**	**Change in Labor Income**	**Change in Jobs**
1,090 ft	DCP Tier 0 Threshold	$6,104,900	$7,213,230	$4,487,828	$2,707,233	72
1,081 ft	2018 Predicted (Elevation)	N/A	N/A	N/A	N/A	N/A
1,075 ft	DCP Tier 1 Threshold	-$3,404,834	-$4,022,974	-$2,502,959	-$1,509,882	-40
1,050 ft	DCP Tier 2a	-$12,688,430	-$14,991,985	-$9,327,507	-$5,626,715	-151

	Threshold					
1,045 ft	DCP Tier 2b Threshold	-$12,688,430	-$14,991,985	-$9,327,507	-$5,626,715	-151
1,025 ft	DCP Tier 3 Threshold	-$12,688,430	-$14,991,985	-$9,327,507	-$5,626,715	-151
895 ft	Dead Pool	-$21,751,265	-$25,700,156	-$15,989,769	-$9,645,650	-258

Table 15. Use Values for Water-Based Recreation and Study and Reference Sites

Source	**Reference Year**	**Reference Location**	**Use Value / Day**			**GDP deflator (2019)**	**Weighted Benefits ($ 2019)**
			Fishing	Motor boating	Weighted Total [a]		
Booker & Colby	1992	Glen Canyon NRA / Lake Powell	$29.22	$24.21	$25.21	0.59938	$42.06
USGS Toolkit Average Values	2016	Intermountain West	$78.83	$34.97	$43.74	0.9414	$46.46
Booker & Colby	1992	Lake Mead NRA	$30.17	$36.16	$34.96	0.59938	$58.33
Kaval	2006	Inter-mountain West	$50.61	$54.79	$53.95	0.80196	$67.28
Kaval & Loomis	1996	Inter-mountain West	$41.31	$44.73	$44.05	0.65153	$67.60
Rosenberger et al.	2016	US Forest Service Region 4	$81.18	$68.03	$70.66	0.9414	$75.06
USGS Toolkit Averages since 1992	2016	Intermountain West	$130.61	$55.77	$70.74	0.9414	$75.14
Douglas & Johnson	1997	Glen Canyon NRA / Lake Powell			$70.84	0.66281	$106.88
Neher et al (2013b)	2011	Intermountain West			$97 [b]	0.86348	$112
Douglas & Johnson	1997	Glen Canyon NRA / Lake Powell			$159.36	0.66281	$240.42

a. Values for fishing were assigned a weight of 0.2, and motor boating, 0.8 following Booker and Colby (1995)

b. Value is for visits to a National Recreation Area in the Intermountain West.

Table 16. Changes in Visitor Spending, Value Added, and User Benefits with Reductions in Reservoir Elevations below the 2018 Baseline

Elevation	Drought Contingency Plan Threshold	Visitor Spending Change	Local Value Added Change [a]	Estimated Change in User Benefits: Low	Middle	High	Very High
		Millions of 2019 Constant Dollars					
Lake Mead							
1,081 ft	Predicted 2018 Visits						
1,075 ft	DCP Tier 1 Threshold	-3.4	-2.5	-4.5	-5.8	-8.6	
1,050 ft	DCP Tier 2a Threshold	-12.7	-9.3	-17.1	-22.0	-32.9	
Lake Powell							
3,603 ft	Predicted 2018 Visits						
3,525 ft	DCP Target Elevation	-34.0	-23.1	-11.8	-21.0	-31.3	-67.3
3,490 ft	Minimum Power Pool	-42.1	-28.6	-14.6	-26.1	-39.0	-83.6

a. Estimates of the changes in local value added include multiplier effects.

Figures

Figure 1. Map of Lakes Mead & Powell

Figure 2. Annual Recreation Visits (Total) to Glen Canyon NRA and Lake Mead NRA, 1979-2018

Figure 3. Monthly Recreation Visits to Glen Canyon NRA (Lake Powell) & Lake Mead NRA, with Linear Trend Lines, 1979 to 2018

Figure 4. Average Monthly Water Level Elevation for Lakes Mead and Powell, 1979-2018, with Linear Trend Lines

Figure 5. Lake Powell Average Monthly Elevation vs. Elevations Where Key Recreational Infrastructure Closed (Access Levels)

Figure 6. Lake Mead Average Monthly Elevation vs. Elevations Where Key Recreational Infrastructure Closed (Access Levels)

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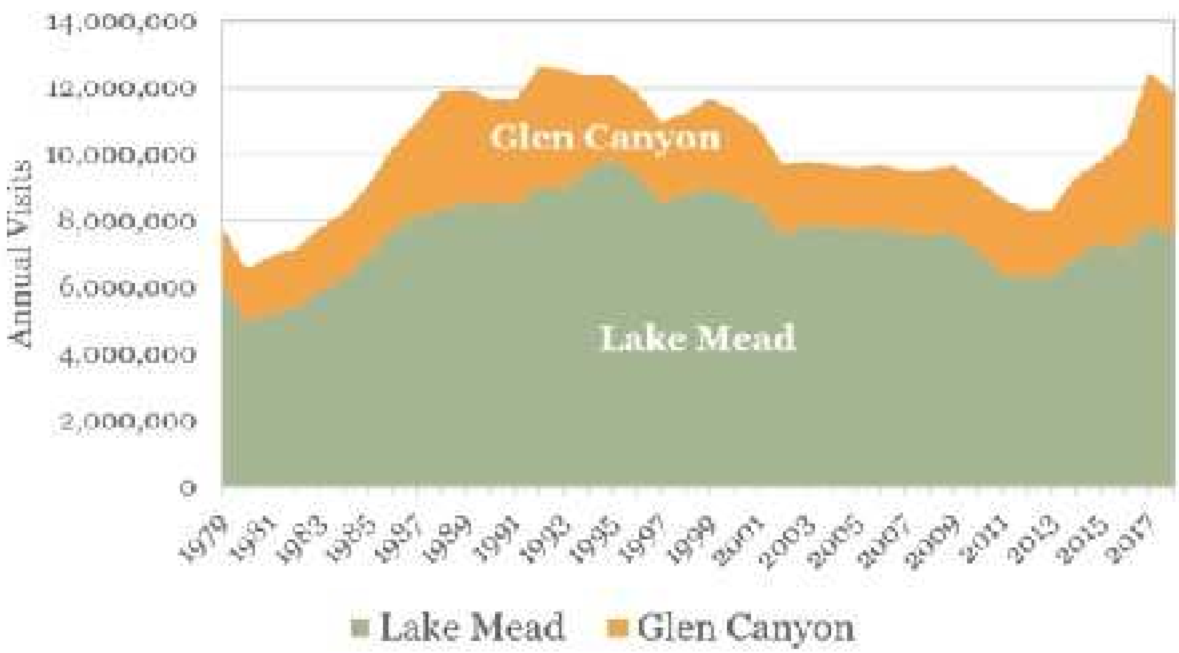

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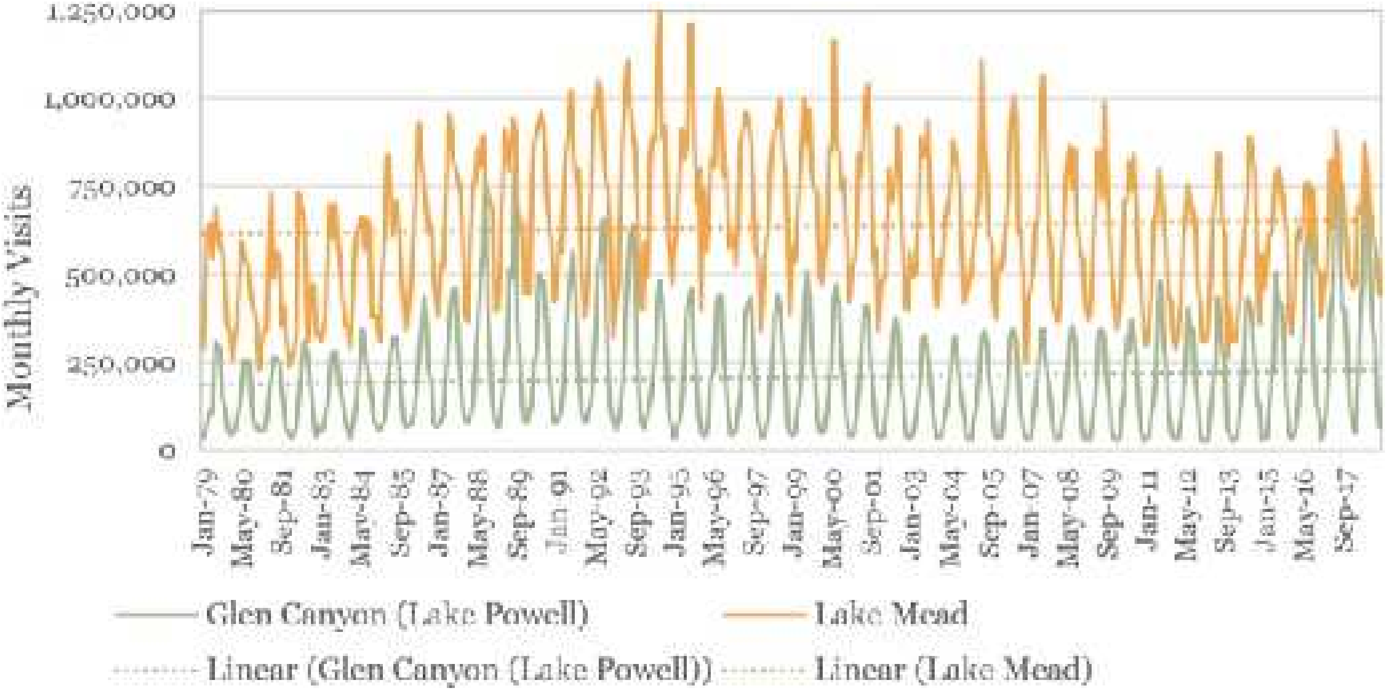

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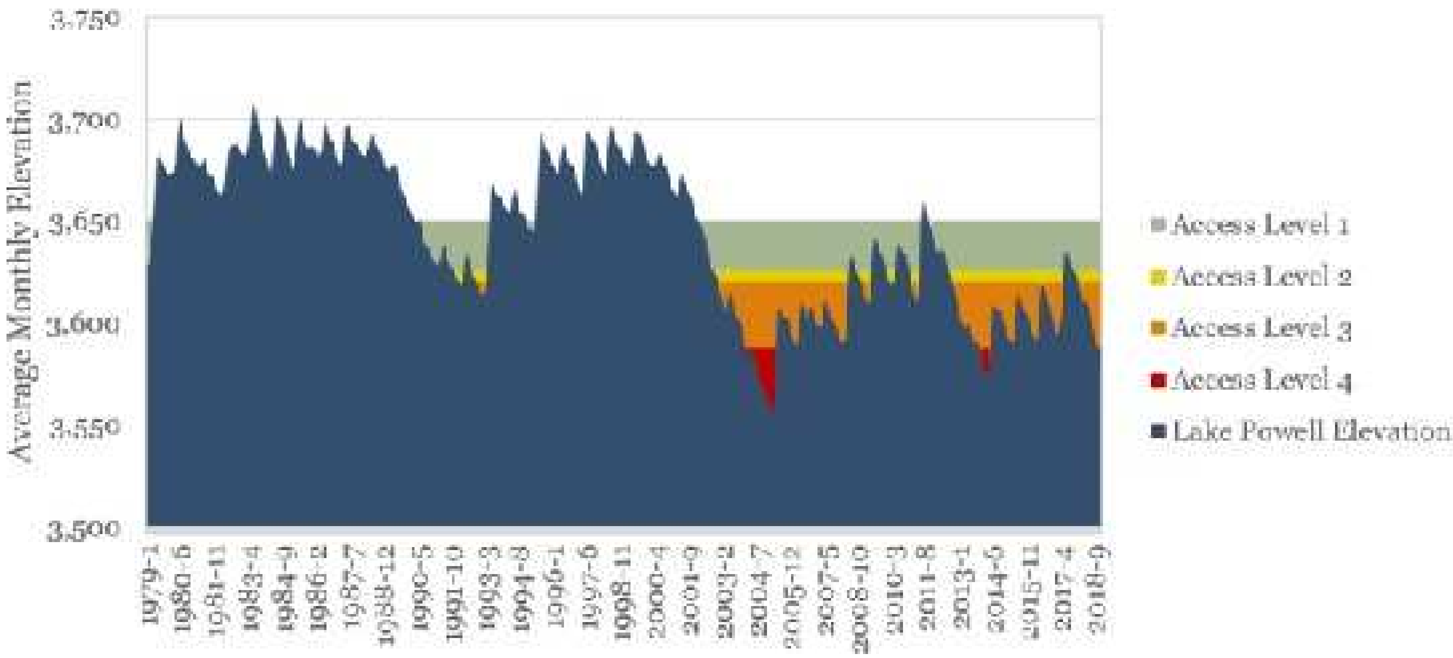

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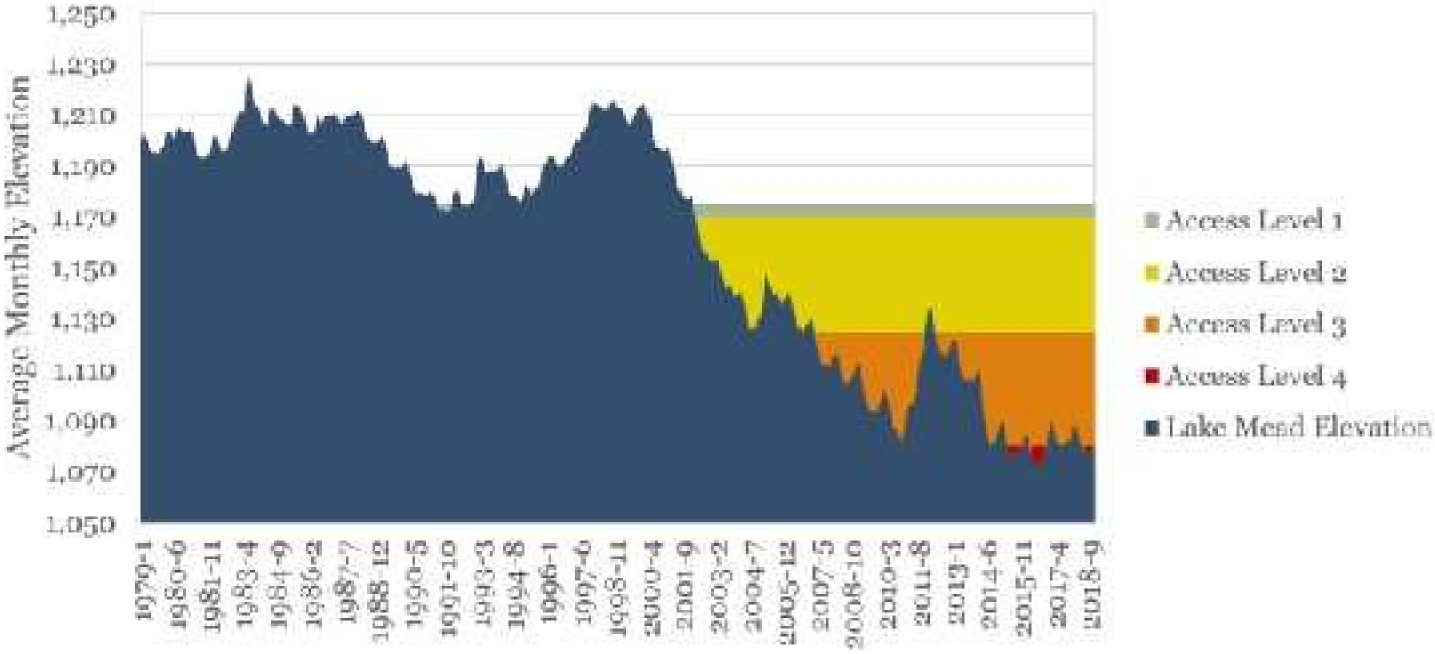

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