

# Using Transportation to Manage Recreation Carrying Capacity

*Nathan Reigner, Brett Kiser, Steve Lawson and Robert Manning*

## Introduction

NATIONAL PARKS ARE CHARGED WITH THE DUAL AND SOMETIMES CONFLICTING MISSIONS of providing public access while protecting park resources and the quality of visitor experiences. When public demand for use is high, this two-fold mission can be daunting. Yosemite National Park may be a poster child for this issue, receiving over four million visits per year. The majority of this use is concentrated at iconic attraction sites, with as many as 15,000 visitors occupying the narrow and confined Yosemite Valley each day (Manning et al. 2003; Lawson et al. 2009; NPS 2012).

The inherent tension between public access to parks and protection of resource and experiential quality is often discussed in terms of carrying capacity (Manning 2007). Originating in the study of biological habitat and range management, carrying capacity's applicability to parks and outdoor recreation has been widely recognized and investigated (Wagar 1964; Whittaker et al. 2011). Carrying capacities can be understood as the amounts and types of visitor use that can be sustained without unacceptable impacts to park resources or the quality of recreation experiences (Grafe et al. 2011; Whittaker et al. 2011). At root, the determination of recreational carrying capacity is a significant visitor-use management decision to be made by land managers and informed by research and public input.

## Objectives, indicators, and standards-based adaptive management

Contemporary approaches to determining and managing visitor use and recreational carrying capacity employ a management-by-objectives framework (Manning 2001; Stankey et al. 1985). Capacity is formulated with the definition of management objectives and associated indicators and standards of quality. Management objectives are typically broad narrative statements about the level of resource protection and the type and quality of recreation experience to be maintained. Indicators of quality are measurable, manageable variables that serve as proxies for management objectives. Standards of quality are benchmarks by which achievement of objectives is judged. Once formulated, indicators of quality are periodically

---

*The George Wright Forum*, vol. 29, no. 3, pp. 322–337 (2012).

© 2012 The George Wright Society. All rights reserved.

(No copyright is claimed for previously published material reprinted herein.)

ISSN 0732-4715. Please direct all permission requests to [info@georgewright.org](mailto:info@georgewright.org).

monitored and evaluated in comparison with standards; management actions are taken if standards of quality are threatened or violated. Monitoring and evaluation of indicators places the conditions visitors experience along the continuum of use-impact relationships and suggests when standards of quality may be violated and management action is required. This process is fundamentally adaptive in the way that cyclic monitoring informs management, and the efficacy of management actions is tested and evaluated through the monitoring program (Stankey et al. 2005).

Like realizing visitor-use objectives, the process of formulating standards of quality can be challenging. Adoption of specific standards of quality, and subsequently carrying capacities, is ultimately a judgment to be made by managers. Their judgments can benefit from public input, especially visitors' evaluations of experienced and desired conditions (Vaske and Whittaker 2004; Manning and Krymkowski 2010). By incorporating such evaluations, along with ecological constraints and administrative capacities, in the formulation and selection of standards of quality, managers can best satisfy competing access and protection demands inherent in visitor-use management.

### **Transportation and recreation**

Transportation and recreation are inherently linked in many national parks (Daigle 2008; Hallo and Manning 2009; Pettengill et al. 2012). This is particularly true of parks such as Yosemite where much of the visitor use is concentrated along roads, trails, and public transit routes. Indeed, the spatial and temporal distribution of visitor use in Yosemite is largely a function of the transportation system (Manning et al. 2003; Youngs et al. 2008; Lawson et al. 2009). The extent of road and trail networks, availability of vehicle parking, and location of transit routes are key determinants of where and how much visitor use occurs throughout the park. From one perspective, this dependence of visitor use on transportation can be an additional challenge for management, as visitors are concentrated within relatively small areas of the park. However, the influence transportation exerts on visitor use also provides powerful leverage for carrying capacity management. If the connections between transportation system performance and the quality of recreation experiences can be understood, transportation can be used as a tool to manage visitor use, maintaining high experiential quality and mitigating some of the challenges of carrying capacity (Lawson et al. 2009; Lawson et al. 2011). These connections are reflected in the second, recreation site- and pedestrian-based track of the Integrated Transportation and Capacity Assessment (ITCA) conceptual models outlined in the introduction to this edition of *The George Wright Forum* (Meldrum and DeGroot, this volume).

### **Study objectives**

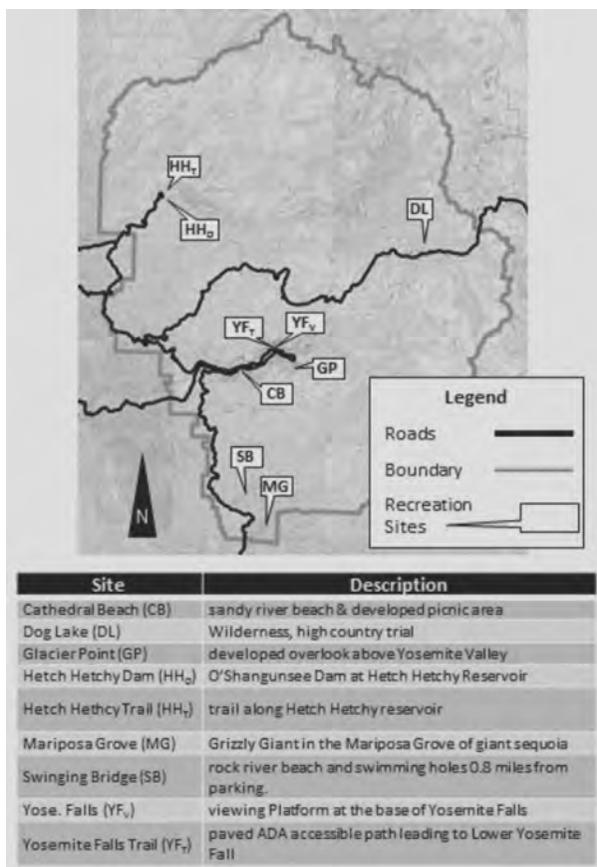
The program of research described in this paper was designed to inform the use of transportation as a tool to help manage visitor use and the carrying capacity of Yosemite. Toward this end, the study seeks a systematic understanding of the relationships between visitor use and experiential quality at recreation sites and how these relationships depend on transportation systems as key origins for visitor use. Specific objectives were to (1) understand how transportation affects visitor use, (2) collect information on crowding-related indicators

and standards of quality, and (3) illustrate the ways in which transportation might be used to manage visitor use and carrying capacity. The program of research employed visitor-use counts and observation, statistical and simulation models of visitor use, and visitor surveys incorporating visual simulations. These methods were applied at nine diverse recreation sites in Yosemite. The program of research is described in general and conceptual terms in the following section. This is followed with an illustration of its application at Hetch Hetchy, an important recreational and interpretive site in the park.

**Study sites**

Like most parks, much of the visitor use in Yosemite occurs in close proximity to its roads. A diversity of dramatic natural features and outstanding recreation opportunities are easily accessible by car and bus. Primary visitor destinations are spread throughout the park, yet are connected by less than half a day’s drive along the park’s extensive road network. Nine diverse sites were selected by managers and researchers to be included in this study (Figure 1). These sites are broadly distributed across the park landscape and transportation net-

**Figure 1.** Study recreation sites in Yosemite National Park.



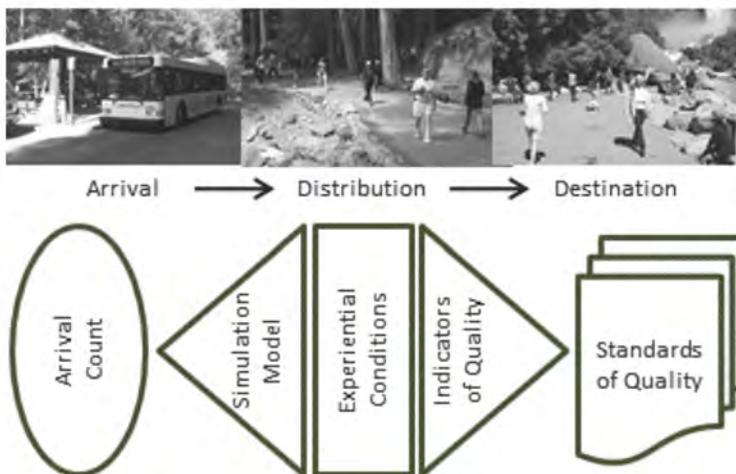
work. Some sites are highly developed, while others lie within Yosemite wilderness. Some are intensely visited; others less so. All sites are accessible by the park's road and trail networks and many are also served by shuttle and tour busses. The sites cannot represent the entire diversity of the park's recreation resources or transportation contexts, but they are inclusive of many visitor uses and geographically extensive.

### **Modeling transportation and the park experience**

Recreation experiences in Yosemite, particularly those at popular recreation sites easily accessible by the park's road network, typically follow a pattern of arrival, distribution, and destination (Figure 2). Visitors arrive at recreation sites, like scenic vistas, beaches, or interpretive sites, via road and trail networks. Upon arrival, perhaps by disembarking from a parked car or alighting from a shuttle bus, visitors distribute themselves throughout recreation sites. They walk paths and negotiate routes to explore rocks and rivers, search for photogenic views, and engage with interpretive installations. While such distribution and activity is part of their recreation experience, visitors are often destined for focal attractions or other essential features within recreation sites. Such destinations can include viewing platforms adjacent to natural features, beaches and swimming holes along rivers, and quintessential trails. This pattern of arrival, distribution, and destination can be broadly interpreted to represent many types of park visits and distills key elements of the park's complex use systems. This schematic pattern mirrors the conceptual models presented in the ITCA introduction (Meldrum and DeGroot, this volume; Figure 2).

Indicators of quality, such as the number of hikers encountered along trails or the number of other visitors sharing a viewing platform, capture and express important qualities of the visitor experience at these destinations (Manning 2011). Standards of quality, identified by park managers and informed by visitors, evaluate the acceptability of indicator variable conditions (Manning 2011). Coupling the progression of arrival, distribution, and destina-

**Figure 2.** Conceptual and methodological models integrating transportation and recreation.



tion depicted in Figure 2 with indicators and standards of quality, levels of visitor use flowing from the transportation system to recreation destinations can be systematically quantified, modeled, and evaluated. The following section of the paper outlines how conceptual elements of arrival, distribution, and destination, along with indicators and standards of quality, are measured and integrated at nine key recreation sites in Yosemite.

### **Modeling arrival, distribution, destination**

Visitors arrive at recreation sites within Yosemite via the park's transportation system. This system includes the modes by which visitors enter and move among locations within the park. Thus, the delivery of visitors by the transportation system is a key determinant of use levels and experiential quality at recreation sites (Lawson et al. 2009; Lawson et al 2011). The arrival of visitors from the transportation system initiates this study's conceptual modeling and is its analytical origin (Figure 2). In this program of research, arriving visitors were counted as they entered recreation sites. Counts were divided by increments of time, in this case by weekday and weekend/holiday and hour of the day. With these divisions, the arrival counts generate both the volume and temporal distribution of visitor use at recreation sites. Using regression models, these recreation site arrival patterns were related to transportation system use and performance. This relationship is the link, depicted in the applied conceptual model of the special edition's introduction, between road and vehicular modeling and recreation site and pedestrian modeling (Meldrum and DeGroot, this volume; White et al., this volume). In these models, entrances to the park and vehicular use on road sections such as Southside Drive in Yosemite Valley were used as independent variables to estimate the amount of visitor use any particular site received. This statistical connection is a primary point of the integration between transportation and recreation experience quality.

After arriving, visitors distribute themselves throughout recreation sites and to destinations. The experiential conditions induced by these distributions, such as the numbers of hikers on trails or the numbers of visitors on viewing platforms, were modeled with computer simulations. A simulation model was built for each recreation site. Using the rate of visitor arrivals, and observations of visitor routing and travel speed collected on-site, the simulations replicate where visitors go and how long they spend there. Beginning with transportation system arrivals, the simulations distribute visitors and estimate the levels of visitor use that can be expected within the sites. These estimates document the numbers of visitors present at destinations such as viewing platforms and beaches, and along trails.

### **Indicators of quality**

The simulation model estimates of experiential conditions at destinations constitute indicators of experiential quality that are specific, measurable, manageable, and relevant to visitors. Indicator variable estimates from the simulation models capture and communicate use levels in a way that can be measured against management objectives for experiential quality. They describe levels of use and quality in terms relevant to and actionable by managers. For this study, three indicators of quality with proven records of utility were selected by Yosemite park managers: the number of people at one time (PAOT) at experiential destinations, the number of people per view (PPV) along a section of trail, and the number of other visitors encountered (encounters) while hiking sections of trail. Each of these indicators is a ratio of

use per area or time. As applied in this study, the numerators of indicator variables are either the number of people or encounters, and the denominators are either the area, length of trail, or period of time. Each indicator variable, as measured for description and presented to visitors for evaluation, expresses both numerator and denominator components of the ratio.

PAOT is used as an indicator of quality for sites whose experiential destinations are areas in which visitors linger (Manning et al. 1996). Examples of such destinations are viewing platforms and beaches. In these locations, it is assumed that the number of other people sharing a space bears a strong relationship to feelings of crowding and freedom, important elements of experiential quality in parks and outdoor recreation (Manning et al. 1996; Fleishman et al. 2007). As noted above, PAOT indicators are essentially ratios of use per space and time. In this study, experiential destinations were depicted in photographs of the area. The area bound by these photographs serves as the denominator of the PAOT ratio. The number of visitors within this area supplies the numerator. Figure 3 depicts a photographically defined PAOT indicator ( $Y$ ) for a recreation site ( $X$ ) at the dam at Hetch Hetchy, an important recreation and interpretive attraction in the park. While the entirety of a recreation destination often cannot be fully depicted in a single photograph, the area depicted may capture the essence of a site's experiential qualities and represent it as a whole. If visitor use and experiential quality can be effectively managed in this essential area, perhaps it will be effectively addressed throughout the site's entirety. When predicting visitor use based on arrival rates, the simulation models estimate the number of visitors that can be expected in the entirety of a destination area. These whole area estimates must be translated into PAOT values for just the area represented in a photograph, and regression models must be used for this purpose. In essence these models define the relationship: if  $X$  number of visitors are in the whole area, then  $Y$  number of visitors are expected to be in the photograph area (Figure 3). The regression equations for this study were created by simultaneously and repeatedly counting the numbers of visitors within the whole area and area of the photograph and then conducting a regression analysis on the paired observations to derive the general relationship. With these methods, PAOT serves as an indicator of quality for recreation destinations such as the dam at Hetch Hetchy.

PPV serves as an indicator of quality for relatively high-use trails (Manning 2011). PPV is similar to PAOT in that it seeks to capture and communicate the visual density of visitors. Contrary to PAOT, however, PPV is suited to characterize recreation experiences that involve movement through or along trails rather than lingering within an area (Manning, et al 2003). Like PAOT, this study operationalizes PPV photographically. A photograph depicting a section of trail bounds the area of the indicator, designating the denominator of its ratio. The number of visitors moving along this section of trail supplies the numerator. When distributing visitors throughout recreation sites, the simulation models can directly estimate the number of visitors expected to be walking along a PPV trail section, eliminating the need for the regression analysis conducted with PAOT. PPV is an indicator variable that can be used to measure and evaluate quality in highly used places where the central experience is based on movement through rather than lingering within an area.

The number of encounters with other hikers is an indicator of quality for relatively low-use trail sections (Vaske et al. 1986; Manning 2011). Like PPV, it seeks to capture and

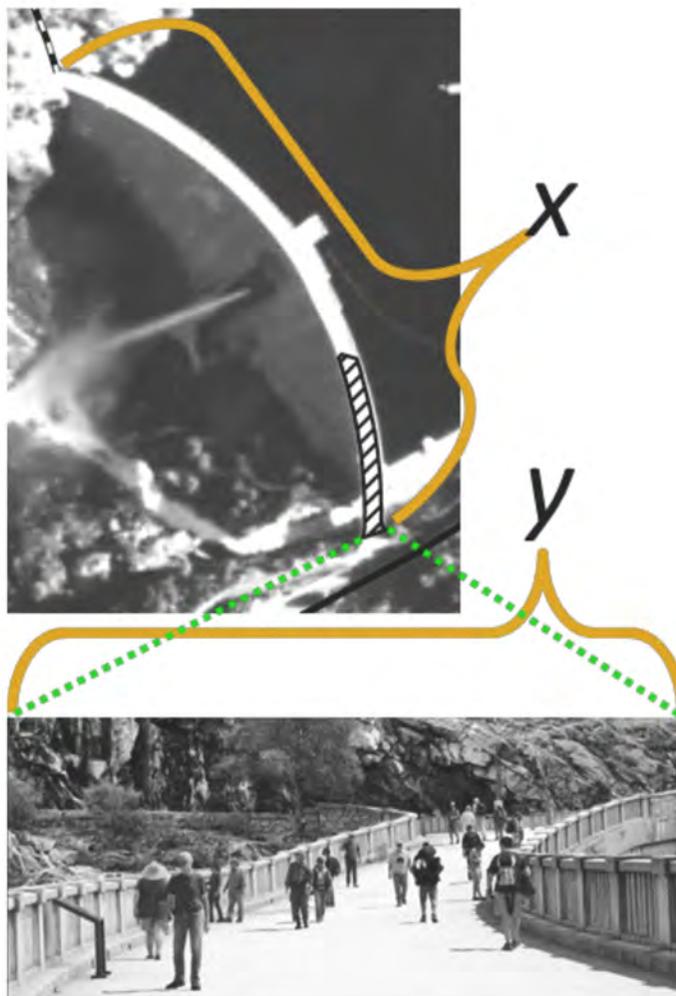


Figure 3. Recreation destination and PAOT photograph area.

express quality and use for recreation where movement through a landscape is central to the visitor experience. Encounters are often used as an indicator for more backcountry-oriented recreation such as wilderness hiking or backpacking (Roggenbuck et al. 1993; Lawson et al. 2006; Watson et al. 2007). Here, experiential destinations are of greater geographic extent than the socially and spatially concentrated experiences characterized by PAOT and PPV. Like those indicators, encounters is a ratio. Its numerator is a count of other hikers met. Its denominator, however, can be more varied than photographed areas of PAOT and PPV. The denominator of an encounters ratio can be either spatial or temporal. A spatial denominator is trail based, for example the number of other hikers encountered along a mile of trail. A temporal denominator is time based, for example the number of other hikers encountered

during an hour of hiking. After designating either a spatial or temporal denominator, the simulation models that distribute visitor arrivals throughout recreation sites calculate estimates of the number of encounters expected.

### **Standards of quality**

Standards of quality define thresholds by which to judge or evaluate the condition of indicator variables. Standards describe, in specific and numeric terms, objectives for the quality of recreation experiences and help to answer the question “how much use is too much.” While formulating standards of quality is ultimately a management judgment, eliciting visitors’ evaluations of the conditions they experienced during their visits can help inform such judgments. However, use levels and associated experiential quality vary dramatically by time of day, day of week, and season of the year. Additionally, use levels and recreation behaviors may change over time in response to management action and increasing or decreasing popularity. Reliance on existing conditions for the formulation of standards of quality limits the ability of research and management programs like that described here to adapt to these sorts of changes (Manning and Krymkowski 2010).

Recognizing the potential for change in visitor-use levels and their relationships to experiential quality, a range of potential scenarios beyond just those currently experienced by visitors must be examined. Photographic simulations of a range of indicator variable conditions depicting use beyond extant levels can inform formulation of standards broad and flexible enough to guide management in the face of short- and long-term change. For PAOT and PPV, a range of indicator conditions were depicted using photographic simulation, and presented to visitor survey respondents. The photographs defining indicator areas were populated, using digital image editing software, to depict varying levels of visitor use. Encounters were simulated using a narrative text describing a range of encounters with other hikers. Visitors to each recreation site were surveyed and presented with a range of indicator conditions, either in photographic or narrative format, and asked to evaluate their acceptability on a scale from -4 (very unacceptable) to +4 (very acceptable). Resulting data allow the construction of acceptability curves that can be used to judge experiential quality at recreation sites under a range of use levels (Jackson 1966; Manning et al. 1996).

A hypothetical acceptability curve is shown in Figure 4. In the example, the curve traces aggregate acceptability evaluations for a range of encounters with other groups along a wilderness trail. The average of visitors’ evaluations fall out of the acceptable range and into the unacceptable range at 10 encounters. This information provides an empirical understanding of visitors’ crowding tolerances, and thus may help inform park managers’ judgments about crowding-related standards of quality. Respondents were also asked to indicate, from among the photo simulations and/or narrative descriptions, the level of use they preferred, the level of use at which park managers should impose limits, and the level of use that would displace them from the area. These multiple evaluations inform management judgment in the formulation of standards of quality associated with experiential quality for range of use levels and visitor arrival rates. The inherent multiplicity of potential standards of quality is depicted in Figure 2.

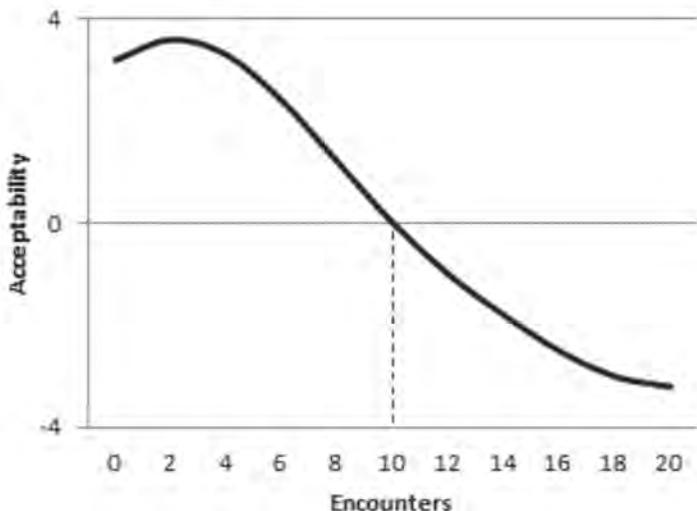


Figure 4. Hypothetical acceptability curve.

### An example: Hetch Hetchy

Hetch Hetchy was one of the recreation areas included in this study. For the purposes of the study, it has two sites, the top of O’Shaughnessy Dam (HH<sub>D</sub>) and the trail beyond the dam leading to destinations north of the reservoir including Wapama Falls (HH<sub>T</sub>). The following description uses Hetch Hetchy to illustrate how the program of research addresses the relationship between transportation and recreation experience quality (as portrayed by the arrival, distribution, and destination conceptual model), and development and application of indicators of quality and visitor-based standards of quality. This empirical approach facilitates use of the park’s transportation system to manage carrying capacity and maintain the quality of visitor experiences. Figure 5 provides a map of the Hetch Hetchy area and its two recreation sites. HH<sub>D</sub> occupies the top of O’Shaughnessy Dam between the locations denoted X<sub>1</sub> and X<sub>2</sub>. HH<sub>T</sub> occupies the trail extending north from O’Shaughnessy Dam, stretching between the locations X<sub>2</sub> and X<sub>3</sub>.

Visitors arrive at Hetch Hetchy via a road, approaching the dam from the south, along which there is vehicle parking. After arrival, most visitors are bound, at the very least, for the top of the dam (HH<sub>D</sub>), and some for a hike along the reservoir (HH<sub>T</sub>) and perhaps onward into the backcountry. During such visits, individuals distribute themselves throughout the recreation sites, walking across the dam, enjoying the view and engaging with interpretive information, proceeding along the trail beyond the dam, eventually returning to their vehicles by crossing the dam again. While distributing themselves in this way, visitors move through destinations whose visitor-use conditions serve as indicators of quality, characterizing the visitor experience of the Hetch Hetchy area. For our Hetch Hetchy example, there are two indicators of quality: PAOT within the photograph area on top of the dam (Figure 5 between X<sub>1</sub> and X<sub>2</sub>), and encounters along the trail beyond the dam (Figure 5 between X<sub>2</sub> and X<sub>3</sub>). The goal of this research was to measure and evaluate the conditions of these indicators of quality based on visitor arrivals from the transportation network.

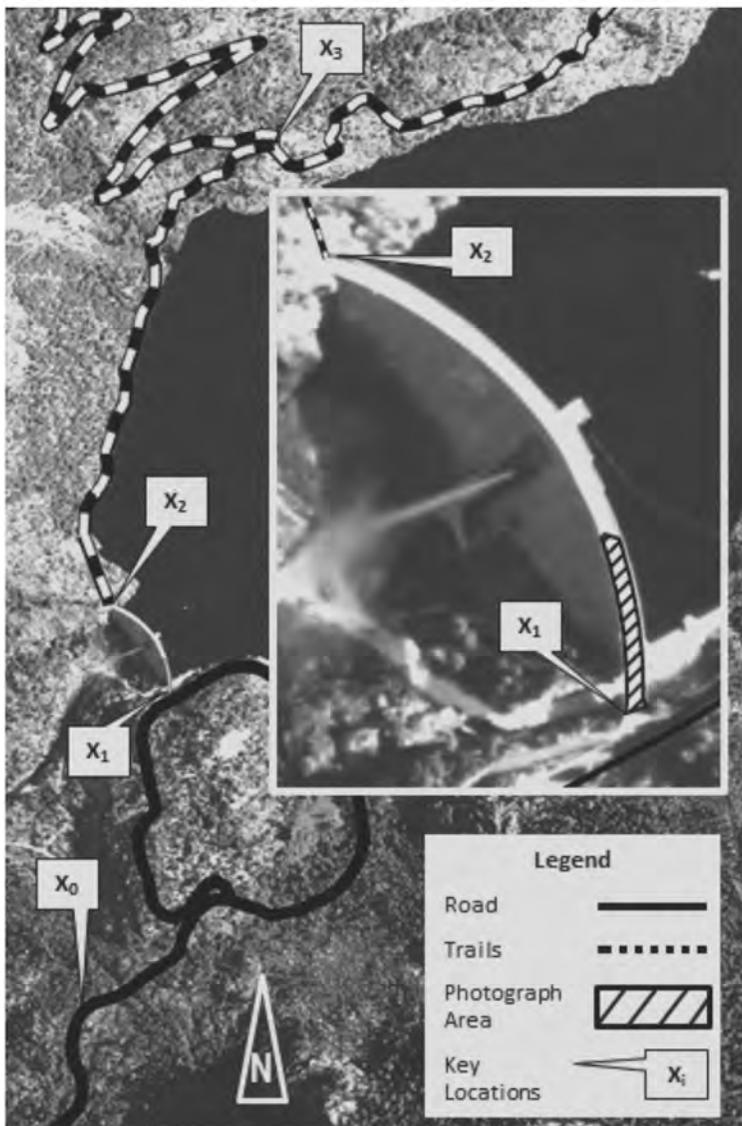


Figure 5. Hetch Hetchy recreation sites.

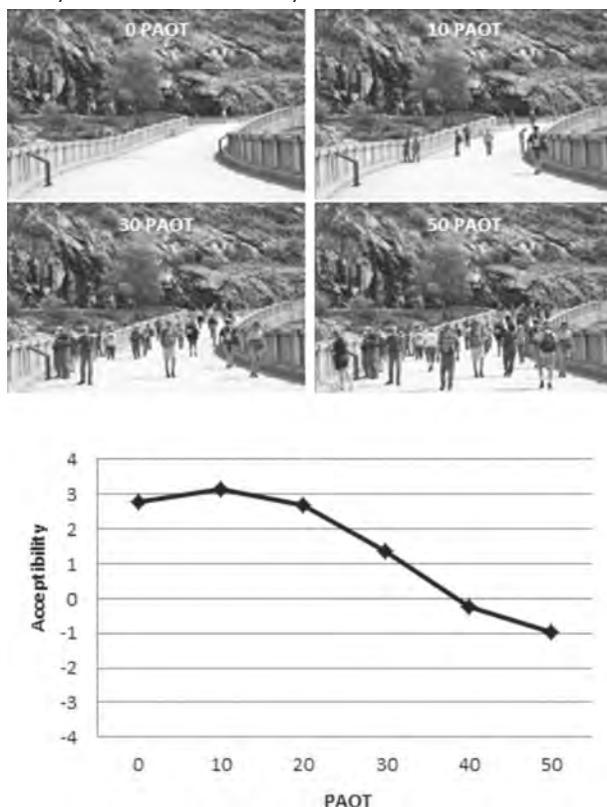
The program of research began with counting the number of visitors arriving to recreation sites via the transportation system. At the Hetch Hetchy sites, this was done with road-based vehicle counters deployed along the access road. By combining these vehicle counts with information about the number of visitors per vehicle from entrance station observations, estimates of the number of arriving visitors were generated.

Next, simulation models replicated the distribution of visitors at recreation sites. Using observations of the behavior of and routes taken by visitors, the conditions of indicators of quality were estimated by simulation models. In the case of HH<sub>D</sub>, PAOT values on the dam

for various levels of vehicle arrivals were estimated. For  $HH_T$ , the numbers of encounters among hiking groups along the trail beyond the dam, between  $X_2$  and  $X_3$ , were estimated.

The simulation and regression models described above were used to estimate the experiential conditions (PAOT and encounters) at Hetch Hetchy based on the number of visitors delivered by the park's transportation system. But are these conditions acceptable or unacceptable? This question was evaluated, from the perspective of visitors, with visitor surveys and standards of quality. For  $HH_D$ , visitors were presented with a series of photographs depicting a range of PAOT levels, representative samples of which are shown in Figure 6. Based on respondent ratings of the acceptability of these photographs, an acceptability curve was constructed (Figure 6) that facilitates evaluation of the PAOT conditions estimated by the simulation and regression models. For example, if simulation modeling estimated that 15 PAOT were at the  $HH_D$  site based on the number of vehicles that arrive via the road to Hetch Hetchy, then that level of transportation system access and visitor use is considered by visitors, on average, as being highly acceptable. This is suggested by the acceptability curve in Figure 6. However, if additional vehicles arrived before any departed and 45 PAOT were estimated to be at the site, then conditions would be, according to aggregated and averaged visitor evaluations, unacceptable (Figure 6). By comparing estimates of indicator conditions

**Figure 6.** Photographic simulations and visitor-based acceptability curve for Hetch Hetchy PAOT.



to the standards of quality formulated from visitor surveys, the performance of the park's transportation system and its influence on experiential quality can be evaluated. This, in turn, can help inform decisions about the crowding-related capacity of Hetch Hetchy.

## **Discussion**

The research presented here addresses one of the primary connections between transportation and recreation: the role of transportation systems as a determinant of recreation use. In shaping where visitors go in parks and when they go there, visitation and crowding at recreation sites can be understood as a function of the transportation systems and facilities that provide access to the sites. The approach used in this study represents this connection in conceptual and methodological models that combine monitoring, simulation, and visitor surveys.

Like many national parks, much of Yosemite's visitor use is centered about its transportation system, especially its roads. Typical visits to Yosemite begin with arrival to the park via one of its five highway entrances, parking personal vehicles or alighting from buses at recreation sites, then proceeding, often not very far from the roads, to experiential destinations such as overlooks, beaches, or interpretive features. Within such patterns, there is an inherent relationship between the number of vehicles on park roads and the volume and timing of visitor use at recreation sites (Manning et al. 2003; Lawson et al. 2009). The conceptual and methodological models used in this research reflect and empirically document these patterns. First, counts of visitors arriving at recreations sites are generated from observation and statistical estimation. Then, simulation models replicate the distribution of visitors throughout recreation sites, estimating corresponding experiential conditions, in terms of indicator variables. Finally, these experiential conditions are evaluated against standards of quality formulated with the help of visitor surveys. This process of monitoring and evaluation helps inform adaptive management of recreation use as it is determined by the park's transportation network.

This integrated program of research provides park managers and scientists with two types of systematically connected information to support decision-making: descriptive and evaluative. The descriptive information characterizes what use *is* occurring. The evaluative component informs management about visitors' perceptions of the amount of use that *ought* to be occurring. In counting visitor arrivals and estimating experiential conditions throughout recreation sites and at destinations, visitor use is described. These levels are then evaluated by visitors using surveys and photo simulations or narrative descriptions. When these methods are joined, the extent and distribution of current use can be described and its impact on experiential quality, in terms of visitor crowding, can be evaluated. By both describing and evaluating visitor use, the conceptual and methodological models lay a foundation for research to support integrated transportation and recreation carrying capacity management.

While the joining of descriptive and evaluative information establishes a foundation for carrying capacity research and management, simulations render this approach flexible and proactive. Flexibility and proactivity allow managers to explore a diversity of alternative and potential future scenarios, assessing their predicted impacts on carrying capacity and recre-

ational quality. This study employs two types of simulations: visual simulations of indicators of quality to depict a range of experiential conditions and simulation models of visitor distribution within recreation sites. Visual simulations of indicators of quality promote flexibility in carrying capacity research and management by representing visitor-use indicator conditions not directly experienced by visitors, including levels of use less than or in excess of current use. Presenting survey respondents with visual and narrative simulations of indicator variables rather than asking them to simply evaluate the conditions they experienced, allows for a full range of use levels, including potential future levels, to be evaluated. This frees managers and researchers from assessing visitors' perceptions of experiential quality and based only on current conditions (Manning et al. 1996; Manning and Krumkowski 2011).

The study's other simulated component, simulation models of visitor distributions, enables a proactive, experimental approach to carrying capacity management and integration of transportation and recreation experiential quality. In essence, simulation models are virtual replicas of the transportation systems, recreation sites, and experiential destinations. These models can be configured to simulate alternative visitor arrival and distribution patterns, estimating the quality of recreation experiences given different transportation systems and management regimes (Cole 2005). This ability allows park managers to experiment with actions in model space rather than on-the-ground, helping to foresee and mitigate the potential political, ecological and economic costs inherent in carrying capacity management (Lawson et al 2009; Manning et al 2003). Indeed, management actions can be investigated before they are necessarily needed, transforming a traditionally reactive approach to a more proactive one (Lawson et al. 2003). By facilitating examination of alternative and future scenarios of use and action, simulations, both simulated indicators of quality and simulation models of visitor distribution, add flexibility and proactivity to the integration of transportation and recreation management.

In building conceptual and analytical linkages between transportation and recreation, this research measures visitor-based crowding standards of quality and monitors crowding-related indicators of quality as a function of transportation system. Thus, this work informs recreation carrying capacity and visitor use management in transportation-based terms. The power of this research approach is not fully realized, however, until the information it provides is applied in management action. Management action in response to threatened or violated standards is explicit in and essential to adaptive visitor-use management. Through its influence as a determinant of experiential quality, transportation can be an important and useful tool for managing recreation carrying capacity.

When considering how to manage transportation in support of high-quality recreation experiences, basic strategies include increasing or decreasing the supply of and demand for recreation resources or altering visitors' behavior and the recreation settings they use (Manning 2011). These strategies are not exclusive. Indeed, most effective management programs seek to enact complimentary strategies. At a recreation site level, if carrying capacities are reached and standards of quality violated, alterations in the transportation system infrastructure and operation can serve to reduce demand and change visitor behavior. Examples of this can include reducing the number of vehicle parking spaces proximate to recreation sites or reducing the frequency and capacity of shuttle buses serving the site. Such reductions can be

complimented with information and education and transit services that direct and transport visitors to relatively little-used sites that may have an excess of visitor capacity, expanding management from a site-specific to a parkwide level. Such redirection must be done with sensitivity to the character and quality of experience unique to each site, ensuring that a range of recreation opportunities is maintained rather than homogenized. Beyond providing information to redirect visitors, informing them about what social conditions they may experience upon arrival at recreation sites may help to alter their expectations so that visitors desiring quieter or more social experiences can plan accordingly.

At Yosemite, as with many national parks, transportation and recreation are inherently connected. A primary connection is the direct influence transportation systems have on the spatial and temporal patterns of visitor use, and subsequently experiential quality, at the recreation sites they serve. Recognizing this connection, transportation and recreation can be integrated for both research and management of visitor carrying capacity and related issues. Conceptualizing the arrival of visitors to recreation sites from the transportation system as the origin of an analytical process, a program of monitoring, simulation, and surveying can observe, estimate, and evaluate experiential quality at recreation sites in terms of transportation system facilities and operations. Ultimately, this research approach can help inform park managers' judgments about visitor carrying capacities for recreation sites and the effects existing and alternative transportation systems may have on the quality of recreation experiences.

## References

- Cole, David. 2005. *Computer Simulation Modeling of Recreation Use: Current Status, Case Studies, and Future Directions*. General Technical Report RMRS-GTR-143. Fort Collins, CO: US Department of Agriculture–Forest Service, Rocky Mountain Research Station.
- Daigle, John. 2008. Transportation research needs in national parks: A summary and exploration of future needs. *The George Wright Forum* 25(1): 57–64.
- Fleishman, Larisa, Eran Feitelson, and Ilan Salomon. 2007. Behavioral adaptations to crowding disturbance: Evidence from nature reserves in Israel. *Leisure Sciences* 29: 37–52.
- Graefe, Alan, Kerri Cahill, and Jim Bacon. 2011. Putting visitor capacity in perspective: A response to the capacity work group. *Journal of Park and Recreation Administration* 29: 21–37.
- Hallo, Jeffrey, and Robert Manning. 2009. Transportation and recreation: A case study of visitors driving for pleasure at Acadia National Park. *Journal of Transport Geography* 17: 491–499.
- Jackson, Jay. 1966. A conceptual and measurement model for norms and roles. *Pacific Sociological Review* 9: 35–47.
- Lawson, S., R. Chaimberlin, J. Choi, B. Swanson, B. Kiser, P. Newman, C. Monz, D. Pettebone, and L. Gamble. 2011. Modeling the effect of shuttle service on transportation system performance and quality of visitor experience in Rocky Mountain National Park. *Transportation Research Record* 2244: 97–106.

- Lawson, S., R. Itami, H.R. Gimblett, and R. Manning. 2006. Benefits and challenges of computer simulation modeling of backcountry recreation use in the Desolation Lake Area of the John Muir Wilderness. *Journal of Leisure Research* 38: 187–207.
- Lawson, Steve, Robert Manning, William Valliere, and Benjamin Wang. 2003. Proactive monitoring and adaptive management of social carrying capacity in Arches National Park: An application of computer simulation modeling. *Journal of Environmental Management* 68: 305–313.
- Lawson, Steve, Peter Newman, Janet Choi, Dave Pettebone, and Bret Meldrum. 2009. Integrated transportation and use capacity research in Yosemite National Park. *Transportation Research Record* 2119: 83–91.
- Manning, Robert. 2001. Visitor experience and resource protection: A framework for managing carrying capacity of national parks. *Journal of Park and Recreation Administration* 19: 93–108.
- . 2007. *Parks and Carrying Capacity: Commons without Tragedy*. Washington, DC: Island Press.
- . 2011. *Studies in Outdoor Recreation: Search and Research for Satisfaction*. 3rd ed. Corvallis: Oregon State University Press.
- Manning, Robert, Wayne Freimund, David Lime, and David Pitt. 1996. Crowding norms at frontcountry: A visual approach to setting standards of quality. *Leisure Sciences* 18: 39–59.
- Manning, Robert, and Daniel Krymkowski. 2010. Standards of quality for parks and protected areas: Applying normative theory and methods in U.S. national parks. *International Journal of Sociology* 40: 11–29.
- Manning, Robert, William Valliere, Benjamin Wang, Steve Lawson, and Peter Newman. 2003. Estimating day use social carrying capacity in Yosemite National Park. *Leisure* 27: 77–102.
- National Park Service. 1997. *The Visitor Experience Resource Protection (VERP) Framework—A Handbook for Planners and Managers*. Denver: National Park Service, Denver Service Center.
- . 2012. Annual Park visitation, Yosemite National Park reports. NPS Stats, National Park Service Public Use Statistics Office. Online at [www.nature.nps.gov/stats/park.cfm?parkid=557](http://www.nature.nps.gov/stats/park.cfm?parkid=557).
- Pettengill, Peter, Robert Manning, Laura Anderson, William Valliere, and Nathan Reigner. 2012. Measuring and managing the quality of transportation in Acadia National Park. *Journal of Park and Recreation Administration* 30: 68–84.
- Roggenbuck, J., D. Williams, and A. Watson. 1993. Defining acceptable conditions in wilderness. *Environmental Management* 17: 187–197.
- Stankey, George H., Roger N. Clark, and Bernard T. Bormann. 2005. *Adaptive Management of Natural Resources: Theory, Concepts and Management Institutions*. General Technical Report PNW-GTR-654. Portland, OR: US Department of Agriculture–Forest Service, Pacific Northwest Research Station.
- Stankey, G., D. Cole, R. Lucas, M. Petersen, and S. Frissell. 1985. *The Limits of Acceptable Change System for Wilderness Planning*. General Technical Report INT-176. Ogden,

- UT: US Department of Agriculture–Forest Service, Intermountain Research Station.
- Vaske, Jerry, Al Graefe, Bo Shelby, and Tom Heberlein. 1986. Backcountry encounter norms—theory, method and empirical evidence. *Journal of Leisure Research* 18: 137–153.
- Vaske, Jerry, and Doug Whittaker. 2004. Normative approaches to natural resources. In *Society and Natural Resources: A Summary of Knowledge*. Michael Manfredi, Jerry Vaske, Brett Bruyere, Donald Field, and Perry Brown, eds. Jefferson, MO: Modern Litho.
- Wagar, J. Alan. 1964. *The Carrying Capacity of Wild Lands for Recreation*. Forest Science Monograph 7. Washington, DC: Society of American Foresters.
- Watson, Alan, Brian Glaspell, Neal Christensen, Paul Lachapelle, Vicki Sahanatien, and Frances Gertsch. 2007. Giving voice to wildland visitors: Selecting indicators to protect and sustain experiences in the eastern Arctic of Nunavut. *Environmental Management* 10: 880–888.
- Whittaker, Doug, Bo Shelby, Robert Manning, David Cole, and Glenn Haas. 2011. Capacity reconsidered: Finding consensus and clarifying differences. *Journal of Park and Recreation Administration* 29: 1–20.
- Youngs, Y., D. White, and J. Wodrich. 2008. Transportation systems as cultural landscapes in national parks: The case of Yosemite. *Society and Natural Resources* 21: 797–811.
- Nathan Reigner**, Park Studies Laboratory, University of Vermont, 81 Carrigan Drive, Burlington, VT 05405; nreigner@uvm.edu
- Brett Kiser**, Resource Systems Group, Inc., 55 Railroad Row, White River Junction, VT; bkiser@rsginc.com
- Steve Lawson**, Resource Systems Group, Inc., 55 Railroad Row, White River Junction, VT; slawson@rsginc.com
- Robert Manning**, Park Studies Laboratory, University of Vermont, 356 Aiken Center, Burlington, VT 05405; robert.manning@uvm.edu