Understanding Recreation Flow to Protect Wilderness Resources at Joshua Tree National Park, California

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Abstract: Joshua Tree National Park (JTNP) has the highest concentration of rock climbing routes in the world and an estimated 250,000 people visit JTNP each year to rock climb. Although less than 5% of rock climbers visit the designated wilderness areas, a steady increase in the number of climbers has focused attention on managing wilderness climbing resources to retain wilderness character. The main controversy centers on rock climber's placing fixed anchors, or bolts, while establishing new climbing routes. Park staff believes that continued unregulated placement of bolts in JTNP's wilderness leads to greater impacts and is unsustainable. This paper describes a method for understanding wilderness climbing in order to develop fair and effective wilderness recreation policy. Behavior and spatial modeling is based on two years of data that include a comprehensive climbing resource inventory, wilderness visitor flow data, and psychological test results. Static and dynamic models consider factors such as travel networks, climbing route difficulty and quality, sensitive resources, landscape complexity, and climber preferences. A comprehensive understanding of recreation flow allows fixed anchor regulations and wilderness management to address site-specific issues.

Introduction

Understanding the relationships between resource impacts, visitor experience and visitor flow is a fundamental issue addressed by Joshua Tree National Park (JTNP) wilderness managers. Over one million people visit JTNP each year due to its proximity to three major metropolitan areas and international acclaim. Nearly 80% of JTNP is designated as wilderness and is thereby managed according to the Wilderness Act of 1964. The Wilderness Act (Section 2[c]) states that wilderness should afford "solitude" and "untrammeled" landscapes.

JTNP is world renowned for the quality of its rock climbing and boasts the highest concentration of rock climbing routes in the world. The number of new climbing routes has dramatically increased since the 1940's, with the most significant period of route development between the early 1970's and present day. There are more than 5,000 published rock climbing routes, and there are hundreds, if not thousands, of unpublished, established rock climbing routes. Approximately 35% of the climbing routes are located within the JTNP wilderness boundary that currently encompasses 593,490 acres of the park. An estimated 250,000 people visit JTNP each year to rock climb. A steady increase in the number of climbers, and climbing routes, has focused attention on managing wilderness climbing resources to retain environmental integrity and wilderness character.

Some of the climbing routes follow cracks that allow the climber to use removable protection, although many routes necessitate fixed anchors in order to safely (relative to no protection) ascend and/or descend. Fixed anchors are defined as any piece of climbing protection that is left in place to facilitate a safe ascent or rappel. Typically, fixed anchors are bolts (1/4"-1/2" diameter and 1/2"-3" long) equipped with small steel hangers.

The main controversy regarding climbing in wilderness centers on rock climber's placing fixed anchors, or bolts, while establishing new climbing routes in designated wilderness. Since February 1993, JTNP has prohibited the placement of fixed anchors in wilderness until it understands the potential environmental and social impacts associated with rock climbing and fixed anchors. Environmental impacts may include the proliferation of social trails and the degradation of cliff and cliff-base ecosystems. In addition, some environmental groups believe that fixed anchors are not acceptable according to their interpretation of the Wilderness Act of 1964. The majority of climbers, on the other hand, believe that fixed anchors are an insignificant impact on wilderness (Waldrup and McEwen 1994, Schuster et al. 2001). The 1998 JTNP Wilderness Management Plan states that rock climbing is an appropriate wilderness activity. However, park staff believes that continued unregulated placement of bolts in JTNP's wilderness leads to greater impacts and is unsustainable. Therefore JTNP must determine a management action that

allows for wilderness rock climbing, including new climbing route development, and protects the finite wilderness resource.

Study Design

This study examined wilderness rock climbing in order to: 1) evaluate the temporal and spatial distribution of wilderness climbers with regard to fixed anchors and sensitive wilderness resources, 2) identify the wilderness climbing resource attributes that are most responsible for attracting heavy use, and 3) design and assess potential fixed anchor regulations and permitting processes.

JTNP wilderness climbing resources are located in the Mojave desert within a complex and rugged landscape dominated by large (up to 300 feet tall) quartz-monzonite formations. There are relatively few designated trails to the climbing sites, and climbers can begin their approaches from about 20 different locations. Approach times vary from five minutes to three hours. Day-use wilderness permits are not required. The majority of climbers gain information about climbing routes from published climbing guidebooks. Landscape vastness and complexity, limited established trail networks, and the typically solitary nature of wilderness climbing dictate the study design.

To understand the relationships between the activity of wilderness climbing and biological resources, cultural resources and wilderness attributes, such as solitude, one must examine the entire wilderness climbing resource system. The wilderness climbing resource system is composed of climbing sites, travel networks, and wilderness climbers. This study combined a climbing resource inventory, wilderness visitor monitoring data, and behavior profiles to model the current spatial and temporal distribution of wilderness climbers and to predict future scenarios.

Erik Murdock, a National Park Service researcher and University of Arizona graduate student, coordinated this study. Fieldwork began in February 2002 and was completed in March 2004. Nineteen volunteers were used to administer surveys, collect climbing resource data and maintain monitoring equipment.

Climbing Resource Inventory

The climbing resource inventory cataloged all established wilderness climbing formations, routes, and access trails. There are over 1800 climbing routes on an estimated 500 climbing formations in JTNP wilderness. The location of each formation was recorded in a GIS (geographic information system) database. For each climbing route on every formation, the location, difficulty, number of fixed anchors, number of fixed anchors at the belays or lowering stations, quality, approach time, and cliff-base environmental condition were recorded. In addition, the safety of the fixed anchors, presence of litter, cliff-base vegetation, and other notable route characteristics were recorded. A relational database was used to link climbing route data to formation locations. In this way, researchers can map the spatial distribution of climbing opportunities as each formation affords a unique opportunity with regard to variances in route difficulty, quality, and fixed anchor availability.

Wilderness climbing resource approach trails were mapped using GPS (Global Positioning System). Although other wilderness users, such as equestrians and hikers, use wilderness trails, the trails serve as the travel network to climbing sites. Trails were classified according to width, use level, and character (braided, discrete, or vague). Conditions at various points along trails were documented and recorded using highly accurate (less than 0.5 meters) GPS techniques so that future studies can return to those locations to monitor conditions. Many of the trails do not deposit climbers at the bases of formation, and therefore climbers typically scramble through boulders or bushwhack short distances. In these situations, travel path locations were estimated and recorded as non-existent. Modeling requirements necessitated that the travel network connects to all destinations. This baseline data is critical not only to modeling, but also because the park plans to monitor both climbing resources and wilderness access trails in order to understand whether the ecological integrity of wilderness resources is being degraded.

Wilderness Visitor Monitoring

Wilderness visitors were monitored to determine the percentage of visitors that are climbers, the temporal distribution of use, and the wilderness access trails that are used. A combination of people counting devices, visual observation, and time-lapse cameras was used to collect data.

Infrared counters and pressure sensitive pads were placed at wilderness access locations to record the time and date of every wilderness entry (Figure 1). Monitoring equipment was placed as close to the designated wilderness boundary as possible. Passive infrared counters, that sense motion and heat differences in an approximately thirty foot square area, were used at low use wilderness access locations that do not have a discrete trail. The main drawback of the passive infrared counter is that it records one event for each group that passes through the monitoring zone. Active infrared counters, that transmit a pulsing infrared beam across a trail, were used in high-use areas with well-used trails and record an event for each person that passes through the monitoring zone. Pressure sensitive pads, that are triggered when the pad is weighted, were used on high-use trails in open areas that preclude above ground monitoring equipment. Monitoring devices were left in place for nine months to two years (depending on wilderness access location) so that seasonal variations and anomalous periods are identified.

Visual observers were positioned at wilderness access locations to record the percentage of wilderness users that are climbers and to validate the people

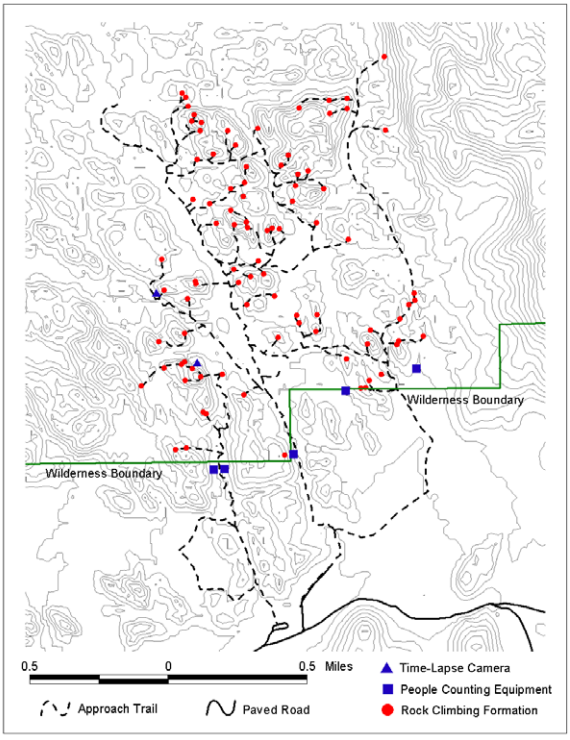

Figure 1. Monitoring equipment locations, approach trails and climbing formations at one of JTNP's many wilderness climbing areas.

counting devices. Visual observers also recorded group size. Random observations were scheduled to sample approximately 15% of the year and were stratified according to day of week and season (Watson et al. 2000).

Time-lapse cameras recorded use patterns at high-use wilderness climbing formations. Cameras were placed at formations that offer a variety of climbing experiences, in effect creating a revealed preference choice experiment. Chosen formations were initially observed to determine the typical amount of time needed to ascend and descend climbing routes. Camera timers were set to expose film during daylight hours at an interval suited to the specific climbing routes so that each climber would be photographed during either his or her ascent or descent. The purpose of the time-lapse photography was two fold. First, it identified the types of climbs that are commonly ascended. Formations that afford a variety of climbing route types insure that climbers can freely choose the difficulty, fixed anchor availability, and quality without being restricted by availability. Second, the photographs recorded the use levels at popular climbing formations. The photograph logs were compared to the wilderness access location monitoring data to determine the percentage of climbers that visit high-use climbing resources relative to the percentage of climbers that disperse throughout the wilderness. The result of this detailed monitoring program is a complete picture, in terms of both space and time, of wilderness climbing resource use. This data also provides JTNP with important baseline trend information.

Climber Behavior Profiles

Climber behavior profiles link destination choice to a climber's individual attributes. Mitchell (1983) describes a climber's decision to visit a specific destination as an opportunity to achieve flow, a euphoric state that occurs during activities that are freely entered into and freely chosen. Climbers seeking flow must successfully match desire, preferences, skill level, and social influences (individual attributes) with an appropriate climbing destination. Studies show that individual attributes, such as experience level, frequency of participation and locus of control, are useful to classify adventure recreation participants and are related to destination attributes such as difficulty, solitude and risk (Fesenmaier 1988, Ewert and Hollenhorst 1989). Ewert (1985) found that more experienced climbers will tend to seek climbing routes that are more rugged, less crowded, and less controlled. However, other researchers found that experience level is related to the perceived detail and specificity of an activity setting and is not correlated to destination attributes (Shreyer and Beaulieu 1986). In other words, dissimilar participants may seek different experiences from the same destination.

JTNP's wilderness climbing resources provide an ideal laboratory to test the relationship between climber's individual attributes and destination choice. Within a relatively small geographic area, JTNP contains thousands of choices that represent every combination of destination setting attributes. A combination of survey techniques was implemented to determine the aforementioned relationship.

The JTNP wilderness climbing survey was designed to collect information on experience level, skill level, frequency of participation, and locus of control. The composite of these attributes describes each climber's level of engagement (Ewert and Hollenhorst 1989). Climbers were asked to state their preferences, using a Likert scale, on the importance of the following destination attributes: solitude, risk, fixed anchors, difficulty, quality, and approach distances. In addition, they were asked to report all of the climbing routes that they visited that day, revealing their preferences for specific destinations. Finally, each survey participant completed a conjoint choice tool that asked climbers to choose preferred destinations from a set of hypothetical choices. Conjoint choice analysis determines mathematical relationships between physical attributes of the landscape and perceptual judgments of wilderness visitors. The analysis inductively calculates importance values for each attribute (Louviere 1988, Haider et al. 1998). It elegantly applies to climber behavior profiles because many of the attributes, such as difficulty and quality, are already quantified. The majority of wilderness climbers is familiar with standard rating sys-

tems, and tends to perceive the wilderness resource in quantifiable terms.

The survey was administered at various locations within JTNP including wilderness access locations, campgrounds, picnic areas, and parking lots. Adult climbers were asked to participate in the survey upon exiting the wilderness or at the end of their climbing day. Survey refusals were recorded to identify non-response bias. Scheduled survey days at each location were stratified according to the day of week and the relative climbing use levels at each location. Preliminary visitor flow models showed that more than 50% of wilderness climbing occurs on weekends and that the majority of wilderness climbers approach wilderness climbing resources from two access locations. During busy periods, up to 60 visitors (climbers and non-climbers) per day use popular wilderness access locations. 430 surveys were administered between September 15, 2003 and February 8, 2004. Eighty eight percent of the wilderness visitors who were asked to complete the survey participated.

Results

The climbing resource inventory, wilderness visitor monitoring data and survey results were combined to understand the spatial relationship between wilderness climbing and fixed anchors. Two years of visitor monitoring showed that 90% of the wilderness climbers used only two of the wilderness access locations. Weekend wilderness visitation varied between 59% and 90% of total visitation depending on the season and wilderness access location. Seasonal variations were predictable, with visitation falling distinctly in the hot, summer months. The percentage of climbers versus non-climbers that visit the wilderness also depended on the season and wilderness access location. At the most heavily used wilderness access location, on average, 54% were climbers. Between January 2002 and December 2003, an estimated 2,150 climbers visited the wilderness from the two most heavily used wilderness access locations.

Time-lapse photography was compared to visitor counts at wilderness access locations. The comparison showed that between 53% and 100% of the climbers, depending on day of week and season, which visited the wilderness, climbed at one of only three climbing formations. Survey results confirm this finding. Fifty five percent of the reported wilderness climbs were located on one of the same three climbing formations.

The climbing resource inventory, when compared to wilderness visitor monitoring data, showed that the geographic distribution of fixed anchors weakly correlates to both high-use trail locations and high-use wilderness formations. In the Wonderland on Rocks wilderness area, 59% of the climbing formations have fixed anchors although visitation was observed and/or reported at only 12% of the climbing formations. In addition, survey results show that only one of the six most reported wilderness climbing routes is completely equipped with fixed anchors. The other five are either entirely naturally protected or are only partially protected by fixed anchors. Forty eight percent of the total reported wilderness climbing routes are entirely naturally protected, 48% are partially protected by fixed anchors, and only 2% are completely protected by fixed anchors. These results lend evidence to the argument that climbers do not visit JTNP to exclusively climb fixed anchor protected climbing routes. Fifty percent of the survey respondents ranked traditional (mostly naturally protected) climbing as their top activity whereas only 15% ranked fixed anchor protected climbing as their preferred activity. Not surprisingly, 73% of the survey respondents visit JTNP equipped with a complete set of climbing hardware for naturally protected climbing routes. Visual observation, climbing resource inventory, and survey results agree that fixed anchors are not the most significant climbing resource attractor in JTNP's wilderness.

If fixed anchors are not responsible for the concentrated distribution of wilderness climbers, what climbing resource attributes are most attractive to JTNP climbers? Climbing route difficulty is a major factor in a climber's decision-making process. Figure 2 shows the percentage of available and reported climbing routes at JTNP according to climbing route difficulty. Difficulty is measured using a standard open-ended interval scale called the Yosemite Decimal System (YDS).

Climbers are not randomly choosing climbing destinations. Thirty four percent of the reported wilderness climbs and 25% of the total reported climbs have a difficulty grade of 7, whereas grade 7 climbing routes only constitute 7% of the total available climbs. Seventy six percent of the reported wilderness climbs have difficulty grades between 7 and 10. These results are in sharp contrast to the distribution of total available climbing routes.

Table 1 lists the five most often reported wilderness climbing routes. These five routes attract 55% of the total wilderness climbing visits. All five routes have difficulty grades between 7 and 10.25. However JTNP's wilderness offers hundreds of routes in that grade range. The other attributes that these route share are quality and approach distance.

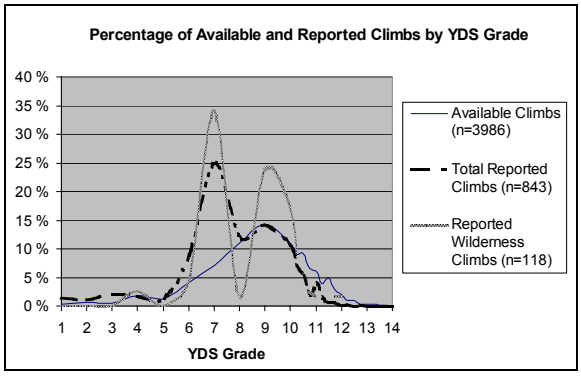

Figure 2. Normalized distribution of available and reported climbs.

Table 1. Top 5 reported wilderness climbing routes.

Name	Grade	Bolts	Quality	Approach
Solid…	10	Some	4	0.98 miles
Figures…	10.25	Some	5	0.98 miles
Hex…	7	None	3	0.96 miles
Dazed…	9	All	3	1.25 miles
Mental…	7	Some	4	1.25 miles

Quality is an interval scaled assessment of a route's aesthetics that considers rock quality, route length, protection, sustained nature, and climbing style. Quality ratings at JTNP range from 0 to 5. A quality rating of 5 denotes an outstanding climbing route and is reserved for routes of unique character. Published JTNP climbing guidebooks list quality ratings next to difficulty grades. Eighty five percent of JTNP climber's own climbing guidebooks and most all climbers are aware of route difficulty and quality prior to visiting climbing destinations. All of the top five reported wilderness climbing routes have a quality rating between 3 and 5. These routes are considered exceptional although there are other, though not many, exceptional climbing routes in the wilderness that have similar difficulty grades and quality ratings.

Approach distance from parking lots appears to be a limiting factor that helps determine destination choice. The top five reported wilderness climbing routes are within 1.25 miles from a parking lot. Hiking times to these climbing routes vary between 30 and 45 minutes. Out of the 843 reported climbing trips (in and out of designated wilderness), not one trip involved more than a 50 minutes approach hike. For perspective, there are over 85 climbing formations, and hundreds of associated climbing routes, that necessitate more than 50 minutes of approach hiking. Figure 3 shows that wilderness climbing trips are more concentrated, relative to overall reported climbing trips, to specific destinations. Revealed preference data (reported climbing routes, time-lapse photography and visual observation) show that climbers are seeking a high return for their hiking investment in the wilderness and are less concerned with specificity when less energy is expended.

This study shows that JTNP climbers that visit the wilderness tend to seek similar destinations, but are the climbers similar to each other? Are climbers with greater experience, higher frequency of participation, and higher locus of control (i.e. level of engagement) more likely to visit the wilderness and/or climb more difficult routes?

The average level of engagement score only slightly increases the further away from roads and parking lots (Table 2). Climbing routes were separated according to hiking approach times. Category 1 includes approaches between 0 and 5 minutes, category 2 includes approaches between 5 and 30 minutes and category 3 includes approaches that are 30 minutes and greater (typically wilderness). Chi-square analysis shows that level of engagement and hiking approach time are related. However, hiking approach times are more closely correlated for lower levels of engagement. In other words, climbers with lower levels of engagement are constrained to lesser approach times, whereas climbers with a greater level of engagement are likely to climb anywhere. When considering the entire population of climbers at JTNP, climbers with a greater level of engagement have a higher probability of exploring wilderness areas. Although the relationship is weak, these results support the findings of Ewert and Hollenhorst (1989), though this study shows that less experienced climbers have greater tendencies to stay out of the wilderness than experienced climbers have of visiting the wilderness.

The correlation between level of engagement and climbing route difficulty is moderate (correlation coefficient = 0.35). The average difficulty level increases with level of engagement (Figure 3). Interestingly, the variance for difficulty is high and relatively the same for all engagement levels. This means that climbers are willing to climb many climbing routes well below their upper difficulty limits. This is an important result for park managers to consider because it means that climbers will visit a wide variety of activity settings. As mentioned earlier, this behavior is less evident in the wilderness where climbers are more particular with their destination choices.

Table 2. Average level of engagement by hiking approach time category.

Approach Category	Average Level of Engagement	Standard Error
1 (0–5 miniutes)	6.95	0.12
2 (5–30 minutes)	7.08	0.15
3 (over 30 minutes)	7.12	0.18

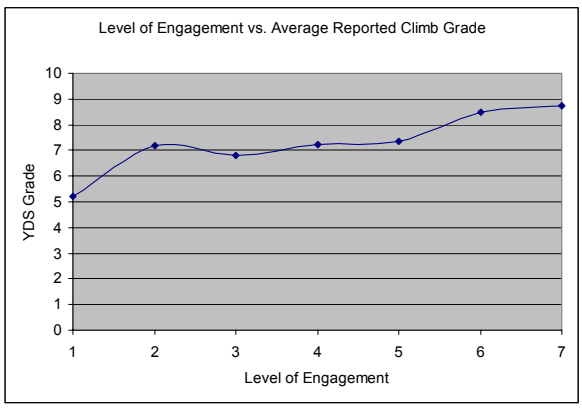

Figure 3. Level of engagement vs. average reported climb difficulty grade (YDS).

Modeling Wilderness Climbing

Wilderness managers strive to protect resources and limit social encounters to an acceptable level. The negative relationship between encounters and experiential quality is considered weak-to-moderate (Stewart and Cole 2001, Manning 2003). However, in a fragile desert with no designated trails, such as JTNP, crowding in the wilderness not only affects solitude, but also creates long standing environmental impacts. Therefore, managers and researchers need to recognize the geographic extent of high-use areas in order to focus management actions and research studies. In this instance, wilderness fixed anchor regulations could range between continuing the existing moratorium to regulating fixed anchors at specific, high-use locations. Modeling allows wilderness managers to see the geographic area that proposed wilderness regulations could affect, and explore the cascading consequences of management plans prior to field implementation.

The boundaries of high-use climbing areas are described in three different ways. First, high-use climbing areas can be defined by the perimeters of high-use climbing formations. Second, high-use areas can be defined by a viewshed that encompasses the high-use portion of climbing formations and areas within a predetermined distance that are within view of each climbing formation. And third, high-use areas can be defined as any area within a buffer zone around trailheads and parking lots equal to the farthest distance to a high-use climbing formation. Cartographic models of the three concepts are developed using GIS (Figure 4).

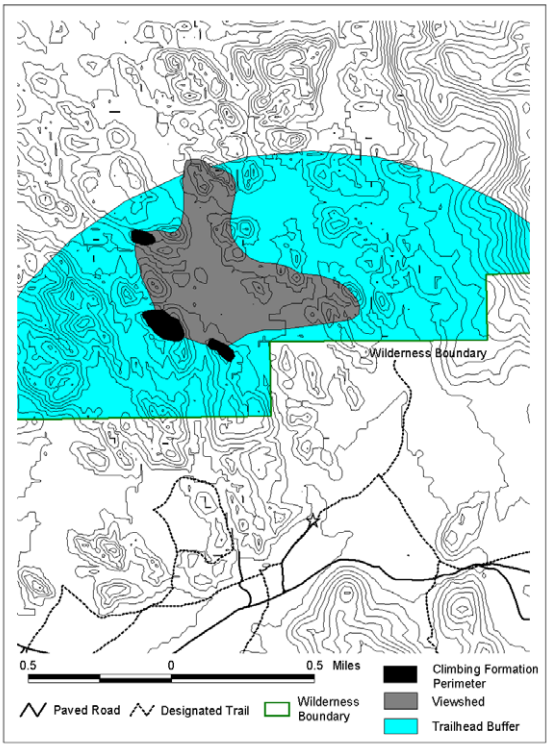

Figure 4. Example of different ways to define high-use climbing area boundaries in South Wonderland, JTNP.

Recreation Behavior Simulation

Wilderness managers need to understand whether new climbing routes equipped with fixed anchors within high-use areas will create crowded conditions at cliff bases or increase social encounters on approach trails to unacceptable levels. They also need to know whether new climbing routes equipped with fixed anchors in low-use areas will attract enough climbers to warrant attention. Recreation Behavior Simulation (RBSim), a model based on artificial intelligence principles to simulate discrete, temporospatial behavior, tests these questions (Gimblett et al. 2002). The following RBSim model is being developed at the time of this writing.

RBSim uses GIS to represent the simulation landscape. Intelligent agents that behave according to hierarchical rules represent wilderness climbers and move through the simulation landscape (Gimblett 2002, Itami 2002). The simulation landscape is composed of a transportation network that links access nodes to destination nodes. The destination nodes represent each of the climbing formations. Each destination node is classified according to climbing resource attributes such as difficulty and quality. Biological and cultural resource locations are also represented in the simulation landscape. Monitoring nodes are inserted into the transportation network to record agent visitation at sensitive resource locations. Agents are grouped according to activity type and preferred activity/setting attributes. Agent behavior is governed by hierarchical rules that are derived from climber behavior profiles and wilderness visitor use data. Wilderness visitor use data also determines the number of agents that enter the landscape during the simulated time period. These “departure curves” reflect the actual temporal variations for specific wilderness access locations.

The simulation environment will provide the opportunity to test and evaluate a variety of scenarios through the manipulation of the number of agents (surrogate climbers) or landscape variables. Test scenarios include increased wilderness use, temporary closures, new climbing routes equipped with fixed anchors and new trail designations. Simulation outputs include the number of social encounters logged by agents and the time and date of every visit at each climbing or monitoring site. The outputs identify locations where crowding or resource impacts, as a result of new scenarios, are probable. Identifying these locations will help determine the shape of the regulated area while avoiding over-regulation.

Implications

A comprehensive understanding of recreation flow in JTNP’s wilderness will help protect resources while avoiding blanket regulations that unnecessarily overburden wilderness visitors. Recognizing high-use areas, behavior patterns, and overall temporospatial distribution allow wilderness managers to explore the

possibility of implementing site-specific solutions. With this information, mangers can consider a fixed anchor permitting process for high-use areas. Climbers would submit permits to place fixed anchors in high-use areas. Using the results of this study, JTNP staff would predict the consequences of the new climbing route based on route attributes, route location, and visitor flow patterns. With this information, they could make an informed decision as to whether or not to grant the permit. Permits would be unnecessary in low-use areas where visitation, regardless of route attributes, is minimal.

Study results show that JTNP wilderness climbers employ a systematic decision-making process when choosing climbing sites. Climbers seek a quality experience and particular site attributes when they invest the energy to reach wilderness climbing areas. The predictable nature of wilderness climbing lends itself to cartographic and simulation modeling techniques that allow wilderness managers to tailor regulations to specific sites within greater wilderness areas.

Acknowledgments

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