



Developing an accessible methodology for monitoring visitor use patterns in open landscapes of Yosemite National Park

By Chelsey Walden-Schreiner, Yu-Fai Leung, Todd Newburger, and Brittany Woiderski

OPEN LANDSCAPES PROVIDE VITAL HABITATS FOR A DIVERSE

array of flora and fauna and serve a number of important hydrologic functions. In addition to their ecological importance, open landscapes provide space for varied human activities. While different types of open landscapes—for example, meadows, dunes, and beaches—serve different ecological and social functions, key shared characteristics include high visibility, walkability, and aesthetic appeal (Falk and Balling 2010; Magill 1992) (fig. 1). The National Park Service (NPS) actively manages for both resource protection and visitor experience, yet open landscapes are still subject to external and internal threats, including climate change, altered hydrologic regimes, encroaching development, and intense visitor use.

Proliferation of visitor-created informal trails is a common type of impact associated with open landscapes. Informal trails, also called social or unauthorized trails, are visually identifiable pathways that fall outside of the park's formal trail system (Leung et al. 2002). Informal trails are often inappropriately located with respect to resource protection objectives, can cause landscape and habitat fragmentation, and can negatively affect visitor experience

Figure 1. View of Yosemite Falls from Cook's Meadow, Yosemite Valley. COURTESY OF YU-FAI LEUNG 2011

Abstract

Open landscapes are common, valued park resources that serve as vital wildlife and plant habitats as well as sites for diverse visitor activities. Although the National Park Service (NPS) actively manages these resources, open landscapes are subject to a variety of ecological pressures exacerbated by anthropogenic threats, including intense visitor use that is often not well documented despite its managerial relevance. Established and valuable counting methods exist to estimate visitor use at static locations, yet open landscapes present special monitoring challenges because of multiple points of visitor access and limited or no containment infrastructure. In this article we present an accessible, replicable, and acceptably accurate method developed for monitoring visitor use and its spatial distribution in open landscapes. This method was implemented in three high-use meadows of Yosemite National Park in the summer of 2011. We highlight the data utility and analytical options, evaluate the benefits and limitations, and discuss the potential for volunteer involvement to sustain longitudinal data collection. Additionally, we provide suggestions of other open landscapes suitable for implementation of this method, such as coastal and urban-proximate units of the National Park System.

Key words

behavior mapping, open landscapes, spatial patterns, visitor use, Yosemite National Park

by visually scarring the landscape (Leung et al. 2011; Marion et al. 2006; Wimpey and Marion 2011).

Effective management of open landscapes, especially those subject to high use with significant informal trail presence, requires an understanding of visitor use and its spatial and temporal patterns. Quantitative information on the location and intensity of visitor use can alert managers to potential resource impacts or areas prone to crowding or other experiential impacts. This need motivated development of the monitoring methodology presented in this study. Many methods for monitoring visitor use in parks and protected areas are designed for static locations like entrance stations or trailheads. Human observers and on-site automated counters are common methods to document visitor numbers at these types of locations and are important tools for estimating use numbers (Cessford and Muhar 2003; Pettebone et al. 2010). However, open landscapes, like meadows, present special monitoring challenges because there are often multiple points of access and limited or no infrastructure to confine visitor use, reducing the effectiveness of some visitor use monitoring methods. Additionally, the inclusion of spatially explicit visitor data can lead to a deeper understanding of the relationship between visitor use and resource impacts when integrated with biophysical data like vegetation condition or water quality.

Methodological considerations

Observational methods allow for the collection of spatial and demographic information. Time-lapse photography and videography are methods that can be used in open landscapes to obtain visitor counts, use patterns, and activities. Studies using photographs or video to observe use have compared counting accuracy with other methods (Arnberger et al. 2005) or derived spatial patterns (Kinney and Clary 1988). Equipment settings, distance, or purposive blurring of images can ensure anonymity of visitors, although image quality may obscure observable characteristics of visitors (Arnberger and Eder 2007). Estimations of gender and age category may still be possible depending on resulting footage (Bradford and McIntyre 2007). While privacy concerns can be mitigated by ensuring individuals are not recognizable, photography and videography were not considered due to the time required to process the data. Other studies capturing spatial information have asked visitors to carry global positioning system (GPS) units, which can provide accurate assessments of visitor movement and be integrated with natural resource data

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(D'Antonio et al. 2010; Hallo et al. 2012). Spatial data are generated directly from the GPS unit, and visitor demographic data can be obtained through a brief survey or researcher observation at the time directions are administered to the visitor. However, multiple points of access inherent in open landscapes may hinder the ability to systematically intercept visitors to carry GPS units, and participant awareness has the potential to influence use. To minimize any interactions with visitors, visitor-carried GPS was not considered further. The use of human observers is also an established and common method, though accuracy and reliability are important issues to address, as variables are subject to observer interpretation (Muhar et al. 2002; McKenzie et al. 2006). Although the use of human observers requires some training as well as time in the field, it does offer the opportunity to engage volunteers in data collection. Volunteers can reduce the burden data collection places on staff time as well as provide protected areas with avenues for stewardship education and outreach.

The objective of this study was to develop an accessible, replicable, and acceptably accurate monitoring method for documenting the amount and context of visitor use and spatial distribution in open landscapes. For the purposes of this study, accessibility meant the method involved low-cost materials and could be implemented and replicated by volunteers with varying levels of technical expertise. An accessible methodology allows for greater integration into other plans for open landscape monitoring that may be operating with limited budgets or personnel resources, and provides the opportunity to engage community partners in collection of managerially relevant data. Accuracy acceptability involved determining if the proposed data uses were appropriate given the measured error. After discussions with park staff regarding the most suitable methodological application, we selected and implemented an unobtrusive observational study.

The study used systematic time scanning and visitor use mapping techniques from methods established in studies of animal behavior, physical activity, and landscape design research. We

adapted these methods to address challenges pertaining to open landscapes with limited or no built features. These adaptations could allow the method to serve as a viable option for use in parks that may be working with volunteers to collect longitudinal data. It is important to note that, while the use of human observers is well established, accuracy and reliability concerns are important to address in applications of this methodology to new environments. Prior to data collection, we assessed mapping accuracy and interobserver reliability to address such concerns and provide an empirical basis for further improvement. We implemented the methodology in three ecologically and socially significant meadows located in Yosemite National Park during summer 2011.

Study area

Located in the Sierra Nevada of California, Yosemite National Park protects more than 3,026 square kilometers (1,169 sq mi) of ecologically diverse forests, riparian habitats, and glacially created landforms (NPS 2011). Yosemite Valley, the Merced River corridor, and the meadows nestled within the park are among the most iconic and highly valued landscapes of the National Park System. In particular, the meadows of Yosemite Valley provide habitats for a diverse array of plants and animals and serve as an integral part of the visitor experience.

As part of long-term research and monitoring associated with the Merced River Plan, NPS staff periodically monitors informal trail networks in eight high-use Yosemite Valley meadows using protocols developed in collaboration with researchers (Leung et al. 2011). Analysis from these monitoring efforts suggests that the number and extent of informal trails in the meadows have increased since the 1970s (Foin et al. 1977; Leung et al. 2011). Data on visitor use of informal trails may help managers understand why informal trail extent is increasing and provide insight on how to mitigate further proliferation.

Methods

To contribute to the current meadow monitoring and management efforts, three of the eight meadows monitored in Yosemite Valley were selected for this study. Researchers and park biologists chose El Capitan, Leidig, and Cook's Meadows in concert after discussions regarding visitor use levels and informal trail proliferation concerns (fig. 2, table 1, next page). We selected unobtrusive direct observation (i.e., trained human observers) for several reasons. First, it has the ability to capture both spatial and descriptive data in large areas with multiple points of access. Second, it also has proven inexpensive and adaptable to allow for adoption into existing monitoring programs. Finally, it does not unduly influence visitors by altering behavior and, ideally, does not have a sizable impact on their experience. We took steps to minimize the potential for visitor-researcher interaction through

careful selection of observation locations. With relatively unobstructed views of visitor activities in open landscapes, observers can gather data on discernible variables like use of the space, visitor demographics, and environmental contexts such as trail conditions and weather that may influence use.

Two observational methods, behavior mapping and momentary time scans, were adapted from previous direct observation studies and combined for the purposes of this research. Used in landscape design and physical activity studies, behavior mapping is an objective observational method for documenting physical use of space, yielding data that support analysis of how people use different environments (Moore and Cosco 2010). This method employs a systematic scan to record the location of persons and desired descriptive data (e.g., age and activity of individuals using a picnic area) within identified target areas. Data are recorded on either electronic or paper maps before observers progress to the next target area. Originally developed for built environments, behavior mapping has included playgrounds, schools, and zoos (Cosco et al. 2010; Proshansky et al. 1976). Observers scan the target area, stopping at the first person encountered to record pertinent variables. The scan resumes from the location where it stopped and the process is repeated until the entire target area has been scanned.

In past research, once the target area has been fully scanned, the observer systematically moves to the next target area or subdivision designated for study (e.g., play equipment to greenway trail segment). However, the lack of built features from which to scan and progress to, and the expansive nature of open landscapes, required adapting the behavior mapping method for application to Yosemite. Thus we instituted successive momentary time scans

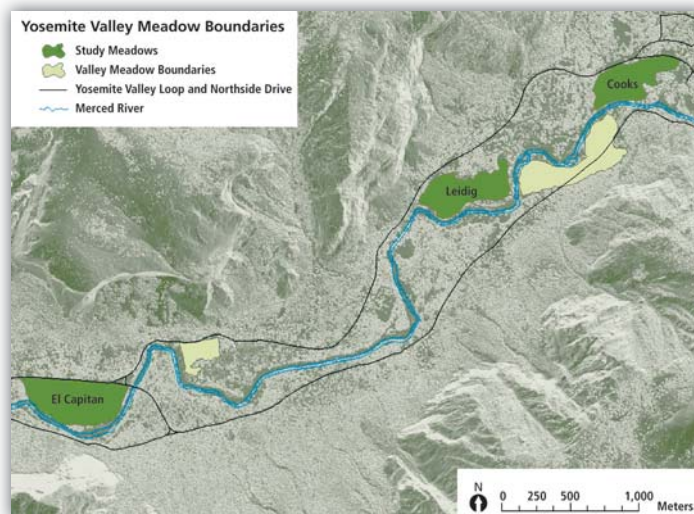


Figure 2. Location of study meadows in Yosemite Valley, Yosemite National Park, California.

Table 1: Yosemite Valley meadow attributes

Meadow	Area (m ²)	Parking availability	Formal trail in meadow? (Yes/No)	Length of informal trails in 2011 (m)
El Capitan	196,384	Roadside	No	5,417
Leidig	141,026	Parking lot	Yes	3,550
Cook's (sections A and B)	94,204	Roadside, parking lot	Yes	2,138

during which observers remained in one location to complete a 360-degree scan of a large area (figs. 3 and 4). In studies of trail use and physical activity, momentary time scans documenting demographic and activity variables using predefined codes have demonstrated acceptable levels of reliability when comparing the proportion of agreement among multiple observers (McKenzie et al. 2006). While momentary time scans have been applied in natural environments previously, the inclusion of spatial data generated from behavior mapping allows for further data analysis of use patterns and resource impacts.

During a pilot test in May 2011, we collected GPS data necessary to create maps on which to record data and established observation locations. We chose three observation sites for each meadow, whose positions were based on lines of sight and complementary visual coverage of the meadow from each location. The meadow boundary, identified by road, river, or forested areas, served as the boundary of the target area for behavior mapping scans. Maps for data collection clearly identified meadow boundaries and emphasized reference features such as easily identifiable trees, snags, and interpretive signs to aid in mapping accuracy. Maps were constructed using GIS software and also contained formal and informal trails as mapped by NPS staff and an aerial image of the study area (fig. 5).

Observers monitored each meadow for 12 hours throughout July and August 2011. They randomly selected which meadow to observe and when from a schedule dividing the sampling periods to cover both weekdays and weekends between 8 a.m. and 8 p.m. Sampling periods were not repeated. A trained observer also randomly selected from which location to make observations and conducted scans of the meadow every 20 minutes for a two-hour sampling period. Observers began the scan by facing north and rotating clockwise. For every individual encountered during the scan, observers documented the spatial location, gender (male or female), age category (youth or adult), and activity at the exact moment of observation. Individuals who reentered the scanning zone were documented again, though not linked to their previous location. The youth age category is defined as individuals age 10 and younger, while the adult category is individuals age 11 and older. These age categories reflect metabolic rate changes as determined in past physical activity research, allowing potential



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Figure 3 (top). Open landscapes serve as a vital resource for plants, animals, and visitor activity.

Figure 4 (bottom). A volunteer collects data in El Capitan Meadow using the paper-based behavior mapping method.

analysis from physical health perspectives (Floyd et al. 2008). Each scan used a new map, resulting in six maps per sampling period.

Multiple observation locations and randomized selection were designed to minimize mapping inaccuracy, caused by either excessive distance from those being observed or hindered line of sight, over time. We assessed the margin of observer error

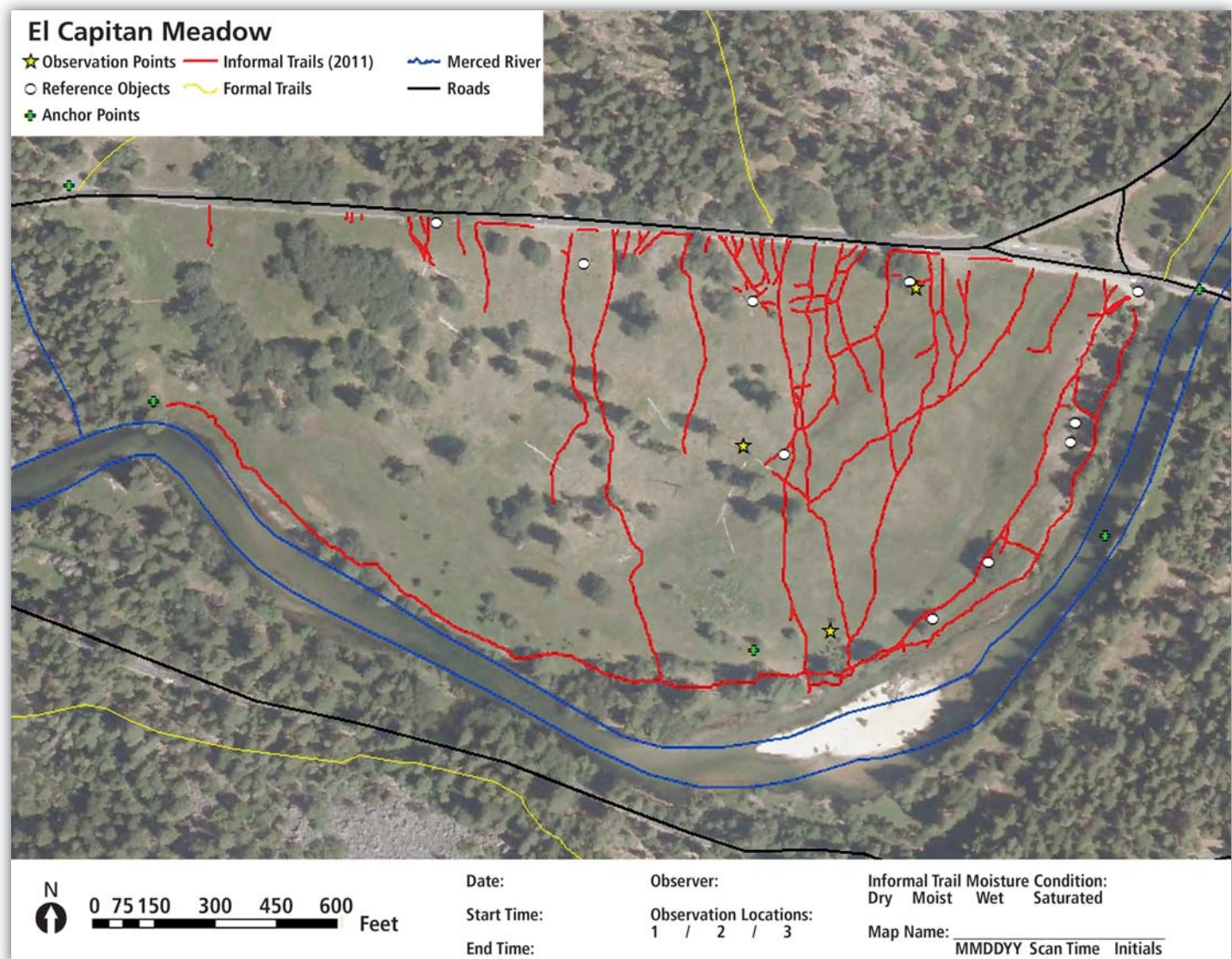


Figure 5. Base map used for data collection in El Capitan Meadow.

during the pilot test by having a trained observer document a second researcher recording GPS waypoints in two of the three study meadows. Because of time and resource restrictions, the pilot test measured accuracy for only one observer. The observer spent 12 hours practicing the method, in addition to several weeks in the study meadows developing the instrument, prior to the assessment. The distance between 22 observed points and the corresponding GPS waypoints were calculated and averaged. The average margin of error was 11.32 m (37.14 ft) with a standard deviation of 7.22 m (23.69 ft).

We collected meadow use data on identical color maps loaded either on a touch-screen tablet computer running a mobile GIS software program or on letter-sized sheets of paper. Both tools were used to assess the benefits and limitations of each as they pertained to method accessibility and volunteer involvement.

Data collected on the tablet computer were in the form of shape files with drop-down menus for variable selection. For data collected on the paper map, a numbered point that corresponded to the same number in a data collection spreadsheet represented the location and attributes of each individual (fig. 6, next page).

Volunteer observers were recruited through the park's daily e-mail report and social media outlets. Prior to data collection, volunteers participated in a meadow orientation and training session. All volunteers collected data on paper maps that were later digitized using the GIS software package.

Findings and discussion

Though the purpose of this article is to discuss observation method development, we also want to highlight the utility of the data. The 18 sampling periods resulted in the creation of 108 maps

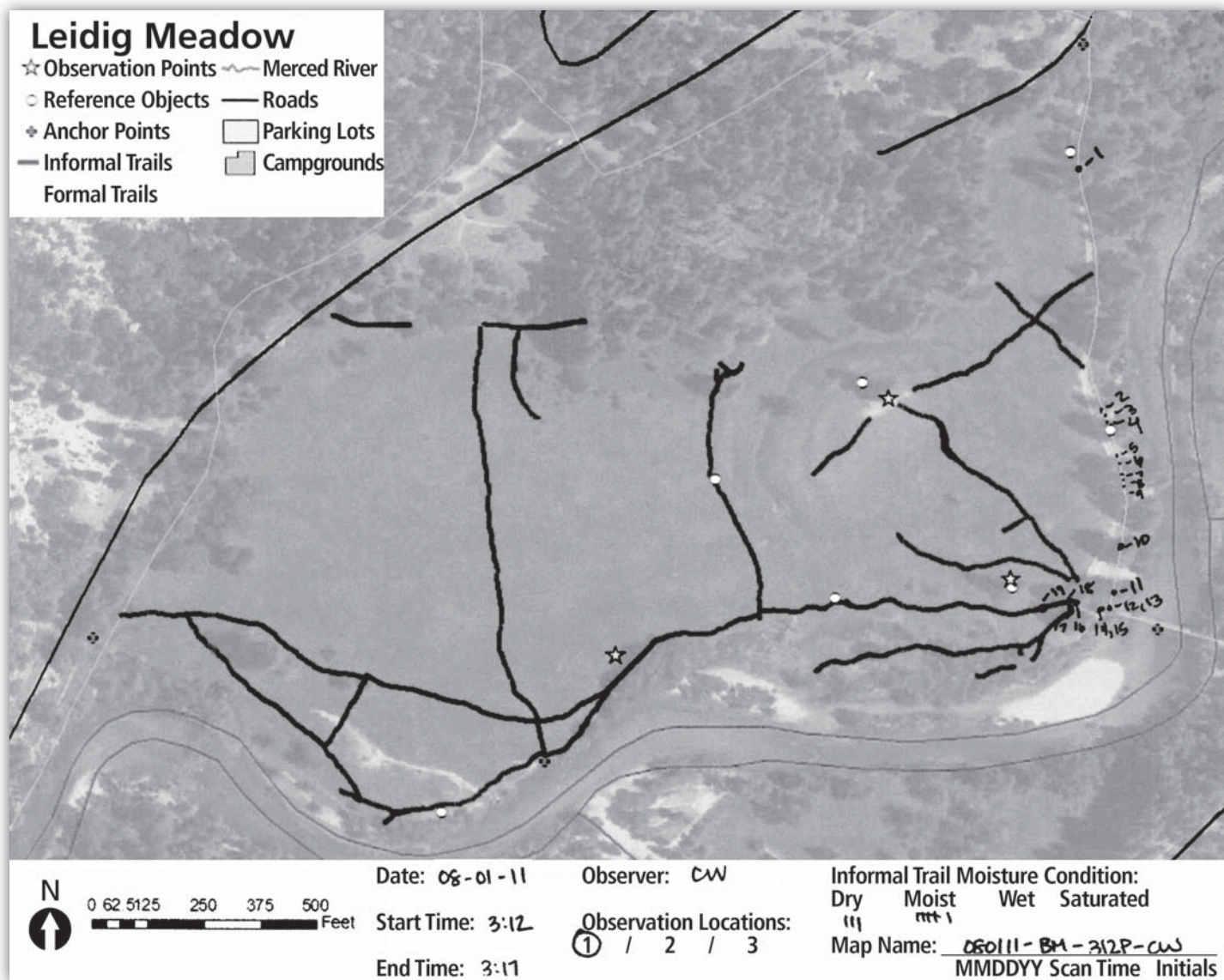


Figure 6. Completed behavior mapping session in Leidig Meadow using paper map.

(36 per meadow) and we summarize observed visitor demographics in table 2. Use numbers were relatively equal across all three meadows and a slight majority of visitors were male adults.

Observational point data generated through behavior mapping also produced maps indicating areas of concentrated use. For example, we used the average nearest neighbor tool to test the randomness of visitor distribution in meadows. For all three study meadows, visitor use was highly clustered and statistically significant. Some clustering in Cook's and Leidig Meadows can be attributed to the formal trails within the meadows. El Capitan Meadow did not have a formalized trail at the time of study. The GIS software enabled us to place three buffers (i.e., 5 m, 10 m, and 20 m [16.4 ft, 32.8 ft, and 65.6 ft]) around the formal trails in Cook's and Leidig Meadows to estimate the percentage of visitor

use attributed to those trails. Buffers incorporated the margin of error and also addressed issues of map scale (i.e., approximately 1 cm [0.4 in] on the map represented 25 m [82 ft] of actual space). Of visitors documented during the study, a total of 68% in Cook's Meadow and 64% in Leidig Meadow were observed within 5 m (16.4 ft) of the formal trails. Though a majority of use was confined to formal trail corridors, more visitors in Leidig Meadow wandered from the formal trail, as illustrated by the percentage increase to 83% in Cook's Meadow and 69% in Leidig Meadow when the buffer extended to 10 m (32.8 ft).

Kernel density estimation (KDE) calculates the density of features within a specified search radius (O'Sullivan and Unwin 2010). In this study, KDE measured the spatial distribution of visitors to allow for exploration of areas of intense visitor use within a search

Table 2: Gender and age* of visitors observed by meadow

	El Capitan	Leidig	Cook's
Male adult	225	275	274
Female adult	153	260	248
Male youth	16	30	30
Female youth	11	28	27
Total observed	405	593	579

*Youth is age 10 and younger.

radius of 50 m (164 ft). Figure 7 compares the KDE of active (e.g., walking, running) and stationary (e.g., photography, sitting) visitor use in El Capitan Meadow.

Behavior mapping data can also use the spatial distribution of visitors to examine patterns of dispersal or level of physical activity. Dispersal patterns may help guide the placement of signage. Additionally, use pattern data can serve as a guide for restoration planning and site design. For example, visitor concentrations in El Capitan Meadow may help support the addition and location of a formal trail. Although it is beyond the scope of this article, future analysis of the meadow use data collected in Yosemite will be spatially linked to informal trail and biophysical GIS data layers to examine relationships among use, informal trail, and biophysical variables.

Method benefits and limitations

We succeeded in developing an accessible method for visitor use monitoring in open landscapes; however, further research and analysis are needed to improve its accuracy, reliability, and efficiency. We tested accuracy of only one observer and found it to be 11.32 m (37.14 ft).¹ We recognize volunteers may not have the level of familiarity with study sites, and additional testing is necessary to better address accuracy levels. The 11.32 m (37.14 ft) measured in this study is in comparison to mapping-grade GPS units that can obtain positions within 2–5 m (6.6–16.4 ft) of true position and consumer-grade GPS units that can obtain results between 5 m and 10 m (16.4 ft and 32.8 ft) of true position, depending on satellite availability and canopy conditions (Wing et al. 2005). The accuracy level may be acceptable for visitor management purposes; however, consideration is warranted for integration with biophysical or other more precisely measured data (e.g., soil composition). Accuracy may also be an issue in areas with very dense trail networks (i.e., informal trail segments 20 m [65.6 ft] apart), in which case a complementary method applied conjointly or a different method applied independently should be considered.

¹ Prior to this accuracy test, we conducted a preliminary assessment after the observer had spent minimal time in the meadow. Initial accuracy estimates prompted relocation of several observation locations to areas with improved sight lines and inclusion of additional reference features. Results from the reported accuracy test occurred after the observer spent several weeks working in the study meadows mapping informal trails and developing the behavior mapping instruments.

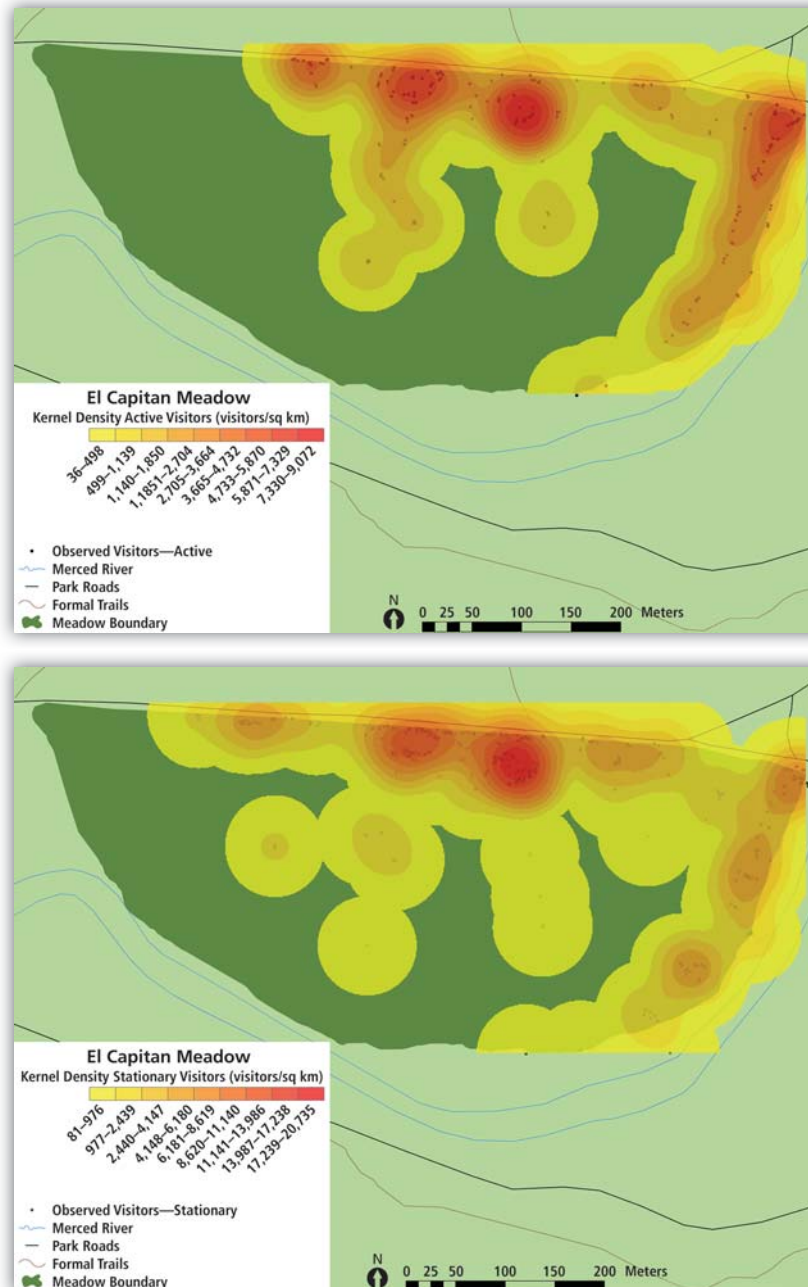


Figure 7. Kernel density estimation of (top) active (e.g., walking, running) and (bottom) stationary (e.g., photography, sitting) activities in El Capitan Meadow.

The large size of the meadows and height of the vegetation during late summer months may have affected observer accuracy. To lessen the potential for errors introduced by subdividing the meadows (i.e., double counts if observers are unsure as to whether the visitor is within their target area or an adjacent subdivision being observed by another volunteer), we sacrificed some accuracy for greater accessibility and so that visitors could experience the meadows without influence from the researcher. Future applications may explore the feasibility of subdividing target areas and

the effect it has on accuracy. Smaller target areas may, in some locations, increase accuracy but potentially render observers more conspicuous. Although no visitors approached observers during the course of this study, interaction is still possible.

One key design consideration of this monitoring method that warranted its use in this context is its accessibility to a wide variety of users, including not only researchers and park staff but also local community and other park volunteers. Volunteers support longitudinal data collection efforts to explore seasonal variations of use. The paper-based mapping tool allows volunteers to collect data after a short training and orientation session at minimal supply cost. The only supplies required are paper maps, data collection spreadsheets, writing implements, timers, and binoculars. Thus paper maps were cost-effective and require little preparation time aside from creating the map itself. However, additional time was needed to digitize the paper maps, and observers were more prone to make errors during the data collection process (e.g., multiple persons numbered 12 on the same map or forgot to collect descriptive data). Additionally, navigating from the paper map to a separate spreadsheet to record demographic data was cumbersome and vulnerable to inclement weather conditions. The tablet computer, equipped with a touch screen and the required drop-down lists, eliminated a majority of the data entry errors during the data collection and digitization process. The tablet was also efficient to use in the field because it eliminated the need to switch between the map and demographic collection spreadsheet. Nevertheless, the tablet required creating a template shape file to house the drop-down menus prior to data collection and the observer needed basic familiarity with the software to collect data. Though the tablet computer helps minimize the time spent processing raw data and eliminates some field collection errors, it does increase material costs and training time. Open source GIS applications developed for mobile devices may be an option in the future to reduce both costs and data processing time.

Lessons learned

The incorporation of volunteers and the lessons learned from this experience can inform future work in other parks and protected areas. First, we included a more detailed meadow orientation with a training session to help the volunteer observers increase their familiarity with the study site and to practice the data collection procedures. Second, it is imperative not to inundate the study area with observers and therefore affect visitor experience. Volunteers make it possible to have recorders at multiple observation locations to help increase survey accuracy, scanning rate, and sampling periods to gain a more robust picture of overall visitor use patterns. However, meadow size and observation site options dictate how many volunteers can be placed at each observation point. Third, when using paper maps, observers should work in

pairs with one individual mapping and the other recording demographic data. This makes the scans more efficient and allows for the mapper to focus solely on the location of the visitor and less on switching from the map to the data spreadsheet. Furthermore, a pair of volunteers affords the opportunity to replicate the data and examine spatial accuracy and measurement error.

The data resulting from this method can aid management in identifying areas of intense visitor use, planning trail maintenance or surface hardening, and planning for restoration. For example, the data from this study were provided to the park staff for consideration as they develop management and restoration plans for the three meadows observed. Specifically, the data assist managers in understanding how visitors use these locations and at what intensities. When considering specific restoration treatments, such as boardwalks and informal trail removal, the data yielded from behavior mapping will help inform the process of both design and restoration.

Although we tested this methodology on the meadows of Yosemite Valley, other high-use and ecologically significant open landscapes are candidates for future applications. Indeed, a major benefit of behavior mapping is the adaptability of the method, which can be tailored to different locations, or even to include wildlife. For instance, beaches, dunes, and tundra are areas in which behavior mapping may serve as a useful method for monitoring use patterns and could be integrated with resource condition data. It is important to note that each site may necessitate adaptation of the method to account for area size, topography, vegetation, and use levels. Further adaptation of the method, like subdivision of the study area or use of pin flags as reference points, may be required to ensure adequate accuracy in these more uniform landscapes. The data generated from modified behavior mapping, even if tailored to a new environment or species, can yield important descriptive and spatial data on use patterns to inform sustainable management of valued resources.

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References

Arnberger, A., and R. Eder. 2007. Monitoring recreational activities in urban forests using long-term video observation. *Forestry* 80(1):1–15.

- Arnberger, A., W. Haider, and C. Brandenburg. 2005. Evaluating visitor-monitoring techniques: A comparison of counting and video observational data. *Environmental Management* 36(2):317–327.
- Bradford, L. E. A., and N. McIntyre. 2007. Off the beaten track: Messages as a means of reducing social trail use at St. Lawrence Islands National Park. *Journal of Park and Recreation Administration* 25(1):1–21.
- Cessford, G., and A. Muhar. 2003. Monitoring options for visitor numbers in national parks and natural areas. *Journal for Nature Conservation* 11:240–250.
- Cosco, N. G., R. C. Moore, and M. Z. Islam. 2010. Behavior mapping: A method for linking preschool physical activity and outdoor design. *Medicine and Science in Sports and Exercise* 4:513–519.
- D'Antonio, A., C. A. Monz, S. Lawson, and P. Newman. 2010. GPS-based measurements of backcountry visitors in parks and protected areas: Examples of methods and applications from three case studies. *Journal of Park and Recreation Administration* 28(3):42–60.
- Falk, J. H., and J. D. Balling. 2010. Evolutionary influence on human landscape preference. *Environment and Behavior* 42(4):479–493.
- Floyd, M. F., J. O. Spengler, J. E. Maddock, P. H. Gobster, and L. Suau. 2008. Environmental and social correlates of physical activity in neighborhood parks: An observational study in Tampa and Chicago. *Leisure Sciences* 30:360–375.
- Foin, T. C., E. O. Garton, C. W. Bowen, J. M. Everingham, R. O. Schultz, and B. Holton. 1977. Quantitative studies of visitor impacts on environments of Yosemite National Park, California, and their implications for park management policy. *Journal of Environmental Management* 5:1–22.
- Hallo, J. C., J. A. Beeco, C. Goetcheus, J. McGee, N. G. McGehee, and W. C. Norman. 2012. GPS as a method for assessing spatial and temporal use distributions of nature-based tourists. *Journal of Travel Research* 51(5):591–606. doi 10.1177/0047287511431325.
- Kinney, J. W., and W. P. Clary. 1998. Time-lapse photography to monitor riparian meadow use. Research Note RMRS-RN-5. USDA Forest Service, Rocky Mountain Research Station, Ogden, Utah.
- Leung, Y.-F., T. Newburger, M. Jones, B. Kuhn, and B. Woiderski. 2011. Developing a monitoring protocol for visitor-created informal trails in Yosemite National Park, USA. *Environmental Management* 47:93–106.
- Leung, Y.-F., N. Shaw, K. Johnson, and R. Duhaime. 2002. More than a database: Integrating GIS data with the Boston Harbor Islands carrying capacity study. *George Wright Forum* 19:69–78.
- Magill, A. W. 1992. Managed and natural landscapes: What do people like? Research paper PSW-RP-213. USDA Forest Service, Pacific Southwest Research Station, Albany, California, USA.
- Marion, J. L., Y.-F. Leung, and S. K. Nepal. 2006. Monitoring trail conditions: New methodological considerations. *George Wright Forum* 23:36–49.
- McKenzie, T. L., D. A. Cohen, A. Sehgal, S. Williamson, and D. Golinelli. 2006. System for Observing Play and Recreation in Communities (SOPARC): Reliability and feasibility measures. *Journal of Physical Activity and Health* 3:S208–S222.
- Moore, R. C., and N. G. Cosco. 2010. Using behaviour mapping to investigate healthy outdoor environments for children and families: Conceptual framework, procedures and applications. Pages 33–72 in C. Ward Thomson and S. Bell, editors. *Innovative approaches to research excellence in landscape and health*. Taylor and Francis, London, UK.
- Muhar, A., A. Arnberger, and C. Brandenburg. 2002. Methods for visitor monitoring in recreational and protected areas: An overview. Pages 1–6 in A. Arnberger, C. Brandenburg, and A. Muhar, editors. *Proceedings of the first conference on monitoring and management of visitor flows in recreational and protected areas*. University of Natural Resources and Applied Life Sciences, Vienna, Austria.
- National Park Service (NPS). 2011. Yosemite National Park: Park statistics. Available at <http://www.nps.gov/yose/parkmgmt/statistics.htm>. Accessed 24 July 2012.
- O'Sullivan, D., and D. J. Unwin. 2010. *Geographic information analysis*. Second edition. John Wiley and Sons, New York, New York, USA.
- Pettebone, D., P. Newman, and S. R. Lawson. 2010. Estimating visitor use at attraction sites and trailheads in Yosemite National Park using automated visitor counters. *Landscape and Urban Planning* 97(4):229–238.
- Proshansky, H. M., W. H. Ittelson, and L. G. Rivlin. 1976. *Environmental psychology: People and their physical settings*. Holt, Rinehart, and Winston, New York, New York, USA.
- Wimpey, J., and J. L. Marion. 2011. A spatial exploration of informal trail networks within Great Falls Park, Virginia. *Journal of Environmental Management* 92:1012–1022.
- Wing, M. G., A. Eklund, and L. D. Kellog. 2005. Consumer-grade global positioning system (GPS) accuracy and reliability. *Journal of Forestry* 103:169–173.

About the authors

Chelsey Walden-Schreiner is a research associate and **Yu-Fai Leung** is a professor in the Department of Parks, Recreation, and Tourism Management at North Carolina State University in Raleigh. They can be reached at cawalden@ncsu.edu and Leung@ncsu.edu, respectively. **Todd Newburger** is a program manager and **Brittany Woiderski** is a biological science technician with Resources Management and Science, Yosemite National Park, California. They can be reached at Todd_Newburger@nps.gov and Brittany_Woiderski@nps.gov, respectively.