

Predicting the Intensity of Recreational Use of Oak Woodland Preserves¹

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Abstract

People value proximity and easy access to protected areas in urban landscapes, including state and regional parks, wildlife refuges, and open space preserves. The popularity of outdoor recreation activities such as hiking and birdwatching has more than doubled in the past 20 years, and surveys indicate that proximity to natural areas is an important factor determining where residents choose to live in California. However, the consequences of widespread recreational use in oak woodlands are largely unknown. The objectives of our study were to assess the spatial variability of recreational activity and identify site- and landscape-level correlates of recreational use of oak woodland preserves in Marin County, California. We collected two data sources to estimate the relative intensity of recreational use among 20 preserves: records of citations issued by open space rangers to recreational users and expert opinion. We used a geographic information system (GIS) database to extract several variables related to site accessibility, site amenities, and land uses surrounding each preserve. We then constructed regression models to identify which variables best predicted relative levels of recreational use for the two data sources and compared their results. Our analysis is a first step towards helping ecologists and land managers better understand variation in the intensity of recreational activity, and we make recommendations for future research on recreation impacts in oak woodlands.

Keywords: Geographic information system (GIS), oak woodlands, open space, recreation.

Introduction

Demand for outdoor recreation is growing, with unknown consequences for biodiversity and natural resources. Natural or environmental amenities – such as protected areas – are positively associated with population growth and economic development in many regions of the United States, especially the American West (Hansen and others 2002). The popularity of outdoor recreation activities – such as hiking, backpacking and birdwatching – has more than doubled in the past 20 years (Cordell and others 2005) and, in surveys, respondents articulate a growing preference for recreation opportunities in natural area parks (for example, California State Parks 2003). Contact with nature has a range of human health benefits (Frumkin 2001) and ecologists value recreation as an ecosystem service supporting human populations (Costanza and others 1997).

In California, people value proximity and easy access to protected areas, including conserved oak woodlands. Hardwood rangelands have a positive influence on property values in adjacent neighborhoods (Standiford and Scott 2002), and environmental amenities, such as parks, are important factors determining where people choose to live in California (Crump 2003). In the San Francisco Bay Area,

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surveys have shown that people prefer to travel less than 30 minutes to access a park or preserve (Bay Area Open Space Council 2004). In Marin County, for example, more than two-thirds of the protected oak woodlands land area is open for public access (*fig. 1*). Recreation is a widespread land use influencing hardwood rangelands, but its potential impacts on oak woodlands are largely unknown.

There is a growing literature on the negative impacts of recreation on plants and wildlife in a range of ecosystems. Recreation is the second-leading cause of endangerment to species on federal lands in the U.S. (Losos and others 1995) and is strongly associated with urbanization patterns (Czech and others 2000). Human recreation results in soil compaction and erosion (Liddle 1997) and reductions in vegetation height, cover and biomass (Cole 1995). In addition, recreational activity correlates with decreases in the abundance and activity levels of invertebrates (Luckenbach and Bury 1983), reptiles (Garber and Burger 1995), birds (Miller and others 1998), and mammals (Fairbanks and Tullous 2002). In a recent study in oak woodlands, we found that protected areas that permitted recreation had dramatically lower densities of mammalian carnivores than protected areas that did not permit recreation (Reed, unpublished data).

In interviews and internal reports, public agency resource managers and conservation specialists have identified documentation of the spatial and temporal variation in the types and intensity of recreational use as a critical gap in knowledge about recreation impacts and management (Gaines and others 2003). Most studies on the ecological impacts of recreation are conducted at a local scale, in a single park or preserve. However, management of human recreation occurs at a larger scale, often across multiple sites. There is likely to be spatial variation in the intensity of recreational use due to differences in accessibility and amenities among preserves. Modeling the variation of recreational use in space could help us manage recreation and better understand its potential impacts on wildlife and biodiversity in oak woodlands.

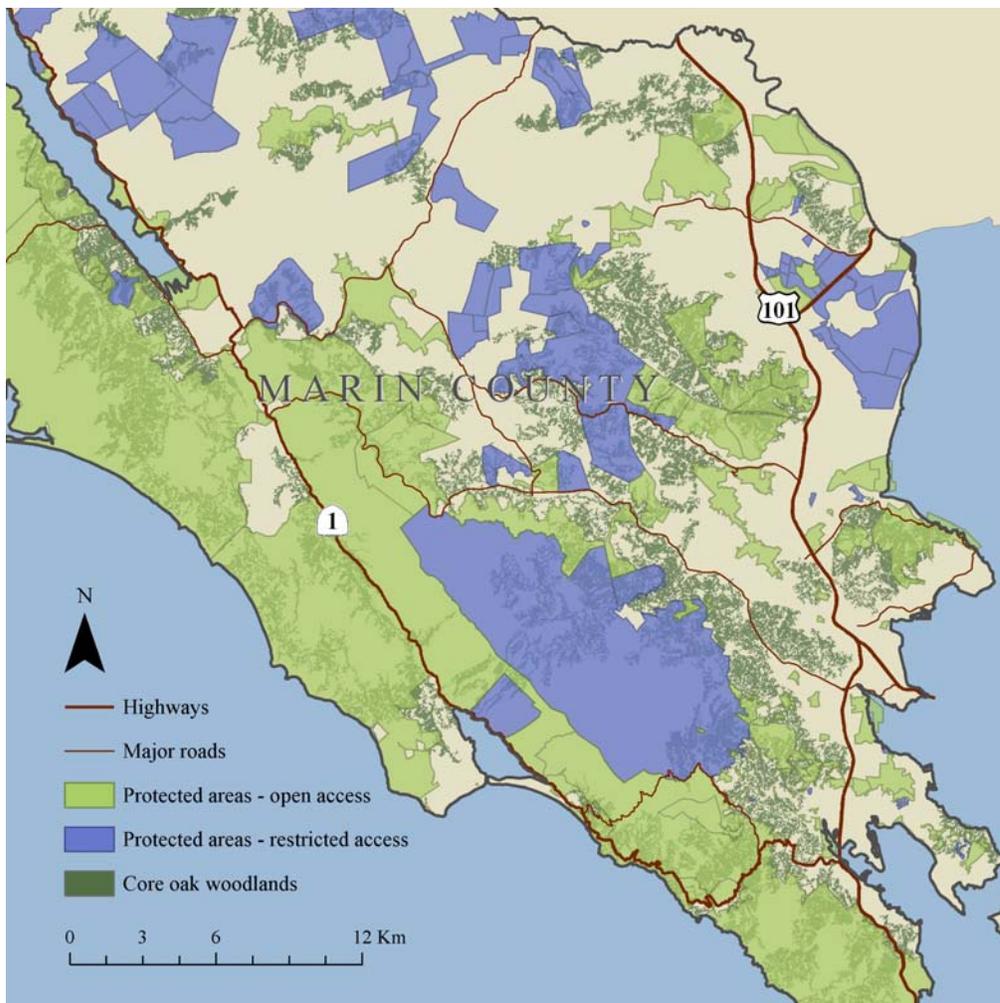


Figure 1—Public access for recreation in Marin County protected areas; 65 percent of total protected land area and 67 percent of protected land with hardwood resources is open to public access. (Source: Bay Area Open Space Council protected lands database)

The objectives of our study were to assess variability in recreational activity among preserves and to identify site- and landscape-level variables that are correlated with the intensity of recreational use of oak woodland preserves in Marin County. We collected two different data sources to estimate the relative intensity of recreational use among 20 Marin County Open Space District preserves. First, we collected records of citations issued by park rangers to recreational users and used this data as an index of the frequency of recreational visitation. Second, we constructed an expert opinion model by asking land managers to classify preserves into categories by level of use. We used a geographic information system (GIS) database to extract several variables related to site accessibility, site amenities, and land uses surrounding each preserve. We constructed regression models based on the two different data sources to select those variables that best predicted the relative intensity of recreational use among preserves and compared the results of the two models. Our analysis is a first step towards helping ecologists and land managers

better understand and predict spatial variation in recreational use intensity, and we make recommendations for future research on recreation impacts in oak woodlands.

Methods

Study area

We conducted our research in Marin County, California, in hillside oak woodlands north of San Francisco Bay (38°0'N, 122°34'W). Situated between the coast and the bay, with elevations ranging between sea level and 800 m, Marin County has a range of climate conditions and vegetation, including coniferous forests, oak woodlands and grasslands, and salt marshes. Marin is densely settled along the US-101 corridor, with a total population approaching 247,000. The county also has significant natural and agricultural resources, including extensive ranch and dairy lands. With more than 57,000 ha of federal, state and county park land, Marin County is a popular recreation destination for local residents as well as visitors from the greater San Francisco Bay Area.

The Marin County Open Space District is a county-level government agency that manages 33 open space preserves, primarily located in the inland portion of the county. The preserves are managed to protect and enhance natural habitat while also providing educational and recreational opportunities for the public. We used the following criteria to select appropriate sites for our study: (1) each preserve had some habitat in oak woodland or oak savannah, (2) each preserve had marked trails or fire roads accessible for recreation, and (3) each preserve was regularly patrolled by Open Space District rangers between 2001 and 2005. The 20 open-space preserves that we selected were distributed south-north through the county and had a mean area of 207 ha (range: 13 to 649 ha; *fig. 2*).

Recreational Use Data

Ideally, we would have constructed our regression models using actual visitor counts as a response variable. However, accurate visitor counts are difficult to collect (Crompton 2001), and a detailed visitor survey was available for only one of the preserves we studied. Consequently, we examined two different data sources that provided an estimate of the relative intensity of recreational visitation among preserves. First, we collected records of citations issued by Marin County Open Space District rangers to recreational users. Because rangers patrol all of the selected sites at regular intervals, visiting each trail and fire road a minimum of two times each year (B. Sanford, personal communication), we assumed that the number of citations issued was proportional to the number of recreational visitors to each preserve.

To minimize any effects of seasonal or annual variability, we summarized records of citations collected over five years, between 2001 and 2005. Marin County Open Space District rangers issued a mean of 50.6 (range: 1 to 202) citations in each preserve during this period. Of these citations, a mean of 41 percent were issued for dog-related infractions, 9 percent for bike infractions, 3 percent for motor vehicle infractions, and 46 percent for other infractions. We pooled total citations in each preserve for all years for our regression analyses.

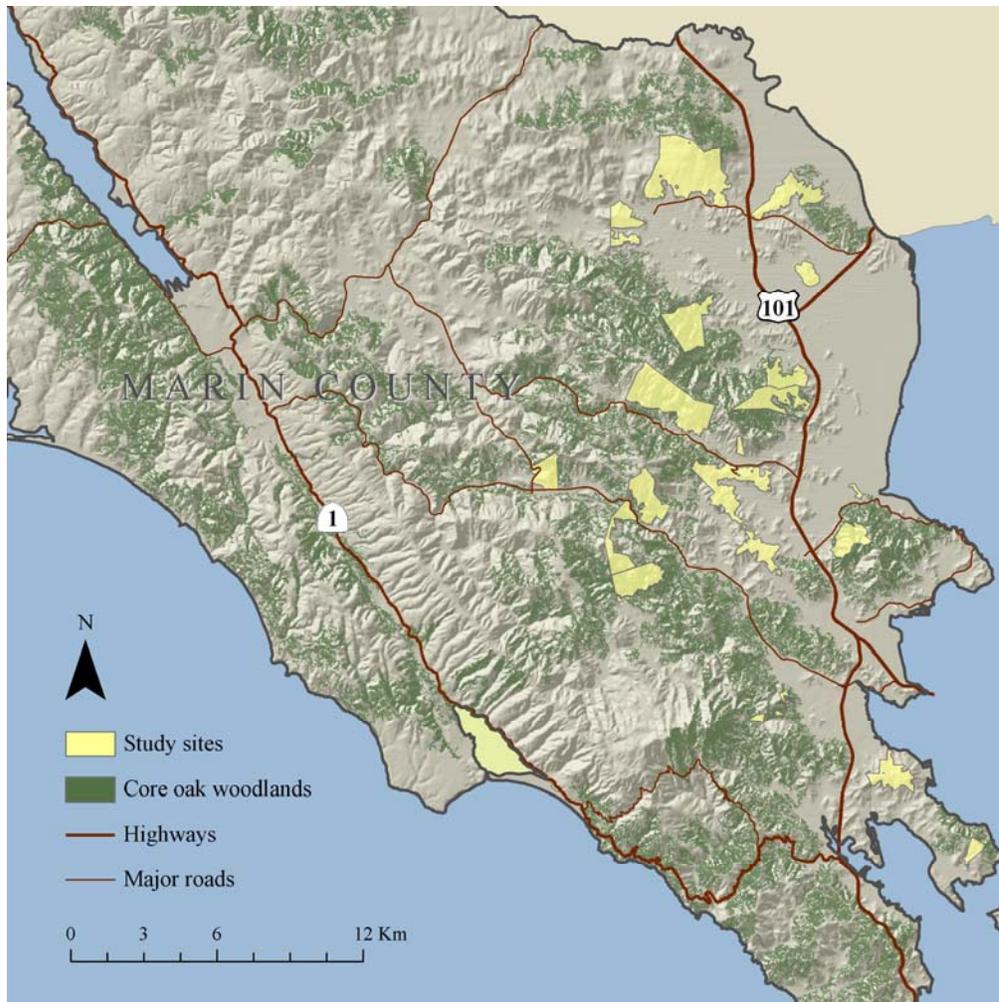


Figure 2—Locations of 20 study sites and core oak woodlands in Marin County, California.

Expert opinion provided our second source of data on recreational use of the preserves. We asked the District’s head ranger to classify the 20 preserves into categories representing their relative visitation rates. The head ranger classified the preserves into three levels of use (low, medium and high), and these classifications were verified by the district’s superintendent. Overall, 5 of the 20 preserves were classified as low-, 8 as medium-, and 7 as high-use.

Site and Landscape Attributes

We collected and extracted 15 site- and landscape-level variables for development of our model (*table 1*). We referred to prior studies on recreational visitation (for example, Termansen and others 2006) as well as our own knowledge of the study system to identify potential predictor variables. The Marin County Open Space District provided us with GIS data on preserve boundaries, fire roads, and trails. We used these data to calculate the area, total trail and fire road distance, and trail and fire road density (distance per unit area) for each preserve. We used preserve maps to count the number of marked entrance gates at each site. We used GIS data provided by the North Coast Integrated Hardwood Range Management Program to calculate topography and land cover variables for each site. We used a 30 m digital elevation

model (DEM) for Marin County to calculate the mean and range of elevations and slope for each preserve. We used CalVeg vegetation data for Marin County to calculate proportions of each site in herbaceous and hardwood land cover. We used Google Maps (<http://maps.google.com>) to calculate driving distances and driving times to each preserve. We assumed that most non-local recreational users would be traveling via US-101 to access the preserves, and we calculated driving distances and times from US-101 to the nearest entrance gate at each preserve. We used a digitized parcel map for Marin County to calculate the number and sizes of land parcels located within 500 m of each preserve's boundary. We calculated the number of suburban (0.04 to 0.4 ha), exurban (0.4 to 8 ha), and rural (> 8 ha) parcels adjacent to each preserve, as well as the total number of parcels. All GIS analyses were conducted in ArcGIS 9 (ESRI, Redlands, CA, USA).

Statistical Analyses

We used JMP 6 (SAS, Cary, NC, USA) to conduct all statistical analyses. We transformed all predictor variables to meet assumptions of normality for regressions (*table 1*). We began by exploring the relationships of each predictor variable with our two response variables. We used linear regressions to explore relationships between predictor variables and total citations and ordinal logistic regressions to explore relationships between predictor variables and level of use. We coded preserves with low levels of recreational use as a value of one, medium as two and high as three, so that positive parameter values in ordinal logistic regressions would correspond to increasing levels of use. We then tested for correlations among the predictor variables. To select a final model for each data source, we limited our analysis to predictor variables that were independent of one another ($r < 0.7$). We included only the predictor variable from each pair or group of related variables (for example, driving distance to US-101 and driving time to US-101) that had the strongest correlation with the recreational use data. We used a mixed, stepwise variable selection process to select the best, most parsimonious model for each response variable. We selected a final multiple linear regression model for the citations data and a final multiple ordinal logistic regression model for the expert opinion data.

Table 1—Site and landscape attributes collected for model development. Data codes and transformations are indicated for each variable.

Site and landscape attributes	Code	Transformation
Site area	AREA	$x^{1/3}$
Number of entrance gates	GATES	$x^{1/3}$
Trail and fire road distance	TF_DIST	$x^{1/2}$
Trail and fire road density	TF_DENS	None
Mean elevation	ELEV_MEAN	None
Elevation range	ELEV_RNG	None
Mean slope	SLOPE	x^2
Proportion of site in herbaceous land cover	P_HEB	None
Proportion of site in hardwood land cover	P_HWD	None
Driving distance to US-101	101_DIST	$\text{Log}(x)$
Driving time to US-101	101_TIME	$x^{1/3}$
Number of suburban parcels within 500m of site boundary	SUB_500	$x^{1/2}$
Number of exurban parcels within 500m of site boundary	EX_500	$x^{1/3}$
Number of rural parcels within 500m of site boundary	RUR_500	$x^{1/2}$
Total number of parcels within 500m of site boundary	TOT_500	$x^{1/3}$

Results

Our exploratory data analyses revealed that several site- and landscape-level attributes were significantly ($p < 0.10$) correlated with each of the recreational use data sources (table 2). Site area, the number of entrance gates, trail and fire road distance, and the numbers of adjacent parcels for all size classes (suburban, exurban, rural and total) had significant, positive correlations with the total number of citations issued in each preserve. Mean slope had a significant, negative correlation with total citations. We did not find significant relationships between trail and fire road density, elevation, land cover or driving distance or driving time from US-101 and total citations issued. For the expert opinion data, we found significant, positive correlations between trail and fire road distance, trail and fire road density and the number of adjacent exurban parcels and the level of recreational use. We did not find significant correlations for the remainder of the variables.

Table 2—Exploratory data analysis. Parameter estimates and model fit statistics are given for linear regressions of site and landscape variables versus total citations issued and for ordinal logistic regressions of site and landscape variables versus level of use. Bold typeface indicates correlations significant at the level $p < 0.10$.

Predictor variable	Total citations		Level of use	
	Parameter estimate	R ²	Parameter estimate	R ²
AREA	0.485	0.31	2.58E-03	0.02
GATES	2.94	0.71	0.0983	0.03
TF_DIST	0.0176	0.23	0.362	0.24
TF_DENS	3.90E-03	0.00	0.0515	0.11
ELEV_MEAN	-1.16E-03	0.00	-1.16E-03	0.00
ELEV_RNG	3.44E-04	0.00	1.74E-06	0.00
SLOPE	-3.78E-03	0.18	-0.0395	0.01
P_HEB	1.10	0.06	0.277	0.00
P_HWD	-1.40	0.11	-0.0176	0.00
101_DIST	-0.375	0.08	-7.19E-04	0.00
101_TIME	-0.660	0.07	-9.83E-03	0.00
SUB_500	0.0564	0.35	9.75E-04	0.07
EX_500	0.836	0.34	0.0176	0.11
RUR_500	0.678	0.21	0.0591	0.03
TOT_500	0.274	0.34	1.01E-03	0.08

Our mixed, stepwise selection process yielded a multiple linear regression model for the citations data that included three significant ($p < 0.05$) predictor variables (*table 3*). Trail and fire road distance and the total number of adjacent parcels were positively related to recreational use intensity, while mean slope was negatively related. This final model explained 66 percent (R^2 adjusted) of the variation in the citations data. Our model selection process for the expert opinion data yielded a multiple ordinal logistic regression model that included two significant ($p < 0.05$) predictor variables (*table 4*). Trail and fire road distance was positively related to level of recreational use, while elevation range was negatively related to the level of recreational use. This final model explained 36 percent (R^2 adjusted) of the variation in the expert opinion data.

Table 3—Multiple linear regression model of site and landscape correlates of total citations issued. All predictor variables selected in the final model are statistically significant at $p < 0.05$. The adjusted R^2 value for the whole model is 0.66.

Model term	Parameter estimate	SE	P
TF_DIST	0.0157	0.0056	0.02
TOT_500	0.231	0.071	0.01
SLOPE	-0.00472	0.00131	< 0.01

Table 4—Multiple ordinal logistic regression model of site and landscape correlates of level of use. All predictor variables selected in the final model are statistically significant at $p < 0.05$. The adjusted R^2 value for the whole model is 0.36.

Model term	Parameter estimate	SE	P
TF_DIST	6.06E-04	2.32E-04	< 0.001
ELEV_RNG	-9.56E-03	5.03E-03	0.02

Discussion

The citations and expert opinion data we collected indicate that there is considerable variability in the level of recreational activity among Marin County Open Space District preserves. In addition, we found a high degree of overlap in the predictor variables selected in final multiple regression models for the two data sources. The concurrence between the models indicates that site attributes are the strongest predictors of recreational visitation to oak woodlands. Although the parameter values are not directly comparable, due to the different modeling approaches, both models indicated a significant, positive relationship between trail and fire road distance and the intensity of recreational use. This result suggests that networks of trails for hiking, biking, and horseback riding are attractants for recreational visitors. Both models also indicated that topography may influence the intensity of recreational use. The citations data model showed a significant, negative relationship between mean slope and total citations issued, whereas, the expert opinion model showed a significant, negative relationship between elevation range and level of use. Mean slope and elevation range were positively correlated ($R^2=0.41$), and negative relationships with these variables suggest that preserves with steeper topography may be less desirable for recreational visitors.

Previous studies in other ecosystems have found that driving distance or travel time from human population centers is a significant predictor of the rate of recreational visitation to parks or forest preserves (Hill and Courtney 2006, Ode and Fry 2006). In our study, we found no significant correlations between either driving time or driving distance to US-101 and either response variable. For the citations data model, we found a significant, positive relationship with adjacent parcel density, implying that local populations, rather than destination visitors, may be the primary users of Marin County Open Space preserves. However, this result was not confirmed by the expert opinion model, and it is possible that adjacent human population density could correlate with increasing numbers of complaints and, subsequently, increasing numbers of citations. In addition, our approach assumed that regional visitors would travel to the sites from US-101. A combined approach, incorporating human population density in different travel ‘time zones’ from each preserve (for example, Hill and Courtney 2006), could clarify the relationships between travel distance, population density and recreational visitation.

Our results were consistent with other studies that have found various site attributes and amenities—including forest type and terrain (Termansen and others 2006), parking availability (Hill and Courtney 2006), and length of available trails (Ode and Fry 2006)—were important determinants of recreational visitation. Our finding that mean slope or elevation range had a negative influence on recreational visitation contrasts with studies of recreation in other habitats, which have found that

visitors prefer undulating rather than flat terrain (Termansen and others 2006). However, hillsides in oak woodlands can be quite steep—mean slopes in the preserves in our study ranged over 25 degrees – and it seems reasonable to assume that visitors to Marin County preferred sites with more moderate terrain. We did not find a significant relationship between land cover type and the intensity of recreation use, although opposing trends with hardwood and herbaceous cover in the linear regressions (*table 2*) indicate that visitors may have a slight preference for open rather than densely forested oak woodlands.

Conclusion

Human recreation is a widespread land use affecting oak woodlands in Marin County (*fig. 1*) and throughout California. A growing body of literature indicates that ecosystems are impacted by both the intensity (for example, Garber and Burger 1995) and spatial extent (for example, Fairbanks and Tullous 2002) of recreational activity. Some factors affecting recreational visitation, such as trail networks, could be influenced by management actions in individual parks or preserves. Other site-level attributes, such as topography, could be taken into account in regional conservation and recreation planning processes. Overall, GIS-based models of recreational visitation, such as those described here, could be useful tools for evaluating trade-offs in land management and acquisition decisions.

The primary limitation of this study was the quality of the data we used to estimate relative levels of recreational activity among preserves. The advantages of the citations data were that it was continuous and collected over a period of five years; however, the relationship between the citations rate and recreational visitation is unknown and the data could be biased by uneven patrol effort or disproportionate citation rates among preserves. The expert opinion data was likely to be relatively accurate, but the small number of ordinal categories provided less power to detect variable relationships. In conclusion, we recommend collecting actual visitor count data to validate the results of model analyses. Accurate and replicated visitor count data can be challenging to collect (Crompton 2001), but is a critical limitation for most multi-site studies of recreation use (for example, Ode and Fry 2006). Collecting such data would clearly improve the predictive power and accuracy, as well as the applicability, of spatial models. In addition, pairing visitor counts with surveys for biodiversity could help us better understand the ecological impacts of recreation in oak woodlands and other habitats. Our study is a first step towards understanding the effects of growing demand for recreation on oak woodlands in Northern California. Ultimately, we hope the results of this and future research efforts can help park managers anticipate the relative intensity of recreational use and mitigate potential impacts to wildlife and biodiversity.

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