Variables Affecting Recreational Use Intensity and its Impact on Carnivore Populations in Parks and Reserves in the Bay Area

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Abstract Previous studies have shown outdoor recreation and exterior development negatively impact wildlife in parks and reserves; however, the variation of recreational use intensity and the relationship between external development and recreation has not been taken into account. This study used GIS analysis to examine how several site attributes and landscape variables contributed to the variation of recreational use intensity in several parks and reserves in Marin County, all of which permit recreation. I used infractions issued to recreators by Park Rangers from 2001 to 2005 as an indicator of recreational use intensity. In order to understand whether variation in the intensity of recreational use impacts wildlife in the preserves, I compared frequency of recreation to carnivore population densities within the parks and reserves, using carnivore scat densities as an index of carnivore population densities. The final model showed positive, significant correlations between recreational use intensity and trail density and the number of suburban parcels within 500m of the preserve. This study did not find a significant relationship between recreational use intensity and carnivore population densities, but further research is warranted. The results of both aspects of my research may help park managers and development planners anticipate intensity of recreational use and potential impacts on wildlife and thus implement management that is in the best interest of protecting interior wildlife without impeding external development.

Introduction

In recent years, widespread suburban and urban development has inspired the establishment of natural reserves and parks to protect natural environments from adverse human impacts. Natural parks and reserves are often open to human visitation and recreation. However the extent to which recreation in parks should be permitted has been controversial; recreation is attractive to both managers and visitors for economic and aesthetic reasons, but is detrimental to ecosystems (Li et al. 2005).

Several studies have concluded that increased human visitation can cause decreased species richness, serious impacts on plant species and soil quality, increased compaction, erosion, fecal contamination of lakes and creeks and vegetation clearance, and spread of weeds and feral animals (Mahan and O'Connell 2005; Andres-Abellan et al. 2005; Pickering and Buckley 2003). In particular, recreation can alarm wildlife, making them flee from on-trail recreationists, causing certain areas of the reserve to be unsuitable for wildlife (Taylor and Knight 2003). Recreational trails can fragment habitat, leading to less available habitat for wildlife population establishment (Fairbanks and Tullous 2002).

Furthermore, studies have shown that larger animals, such as carnivores, have larger "alert distances" and are therefore more affected by human visitors (Blumstein et al. 2005). Carnivores have important ecological roles and in many cases are considered keystone species (Noss et al. 1996). Carnivores interact with other species as predators and removal or introduction of predators may have unpredictable, negative affects on other species (Glen and Dickman 2005). Therefore, changes in population density or species composition of the carnivore community may impact the entire ecosystem (Hilty, 2000; Crooks, 2002).

The intensity and type of recreation has been shown to have significant impacts on wildlife behavior (Taylor and Knight 2003). Previous studies show sites that permit recreation had significantly lower overall native carnivore scat densities than sites that do not permit recreation (Sarah Reed, personal communication).

As part of a larger project on the impacts of recreational use and landscape context on northern California protected area, this study focuses on which variables correlate with recreational use intensity in Marin County Open Space District preserves and, in turn, how recreational use intensity affects carnivore populations. This study determines recreational use intensity as the number of visitors that access a particular park or reserve. Specifically, this study

focuses on the following variables as possible correlates of the intensity of recreational use: number of entrance gates, distance from highway 101, trail and fire road density, and the number of suburban, exurban, and rural parcels within 500 meters of each preserve.

Marin County Open Space District preserves vary in size, type, and surrounding environments and therefore they are excellent sites to study the impacts of development and recreation. They are a local government agency that manages public open space in Marin County. Marin County Open Space District protects diverse, natural northern California environments such as salt marsh, oak-bay woodlands, grasslands, and savanna.

This study is part of a larger project examining the impacts of human disturbance to carnivores in protected areas. By determining recreational use indicators and how recreational use affects carnivore populations, we can more accurately predict recreational use in a particular area and how interior wildlife is affected.

Hypotheses 1) The two most important factors in determining recreational use intensity are proximity to highway 101 and proximity of the preserve to suburban development.
2) Recreational use intensity will be negatively correlated with carnivore population densities.

Methods

Study Site I studied the following nine preserves, all of which permit recreation and are managed by the Marin County Open Space District: Mt. Burdell, Rush Creek, Loma Verde, Terra Linda, Cascade Canyon, Loma Alta, Indian Valley, Verissimo Hills, and Little Mountain in Marin County (Fig. 1).

Data Collection All of the recreation data used in this study was collected in Marin County by the Marin County Open Space District over a period of four years, from 2001 to 2005. I determined recreation behavior and intensity based on citations issued by Park Rangers at each open space parcel studied. The carnivore scat data was collected by Sarah Reed over a period of two years, from 2004 to 2005.

This study obtained all of the data for GIS analyses from the North Coast Research and Extension Group's database of geographical information on Marin County. I used the following layers of data: Marin Open Space District fire roads, Marin Open Space District trails, Marin Open Space District parcels, Marin County Parcels, and Marin County roads. The carnivore data

was provided by Sarah Reed who collected and analyzed carnivore population densities in preserves over a two year time period.

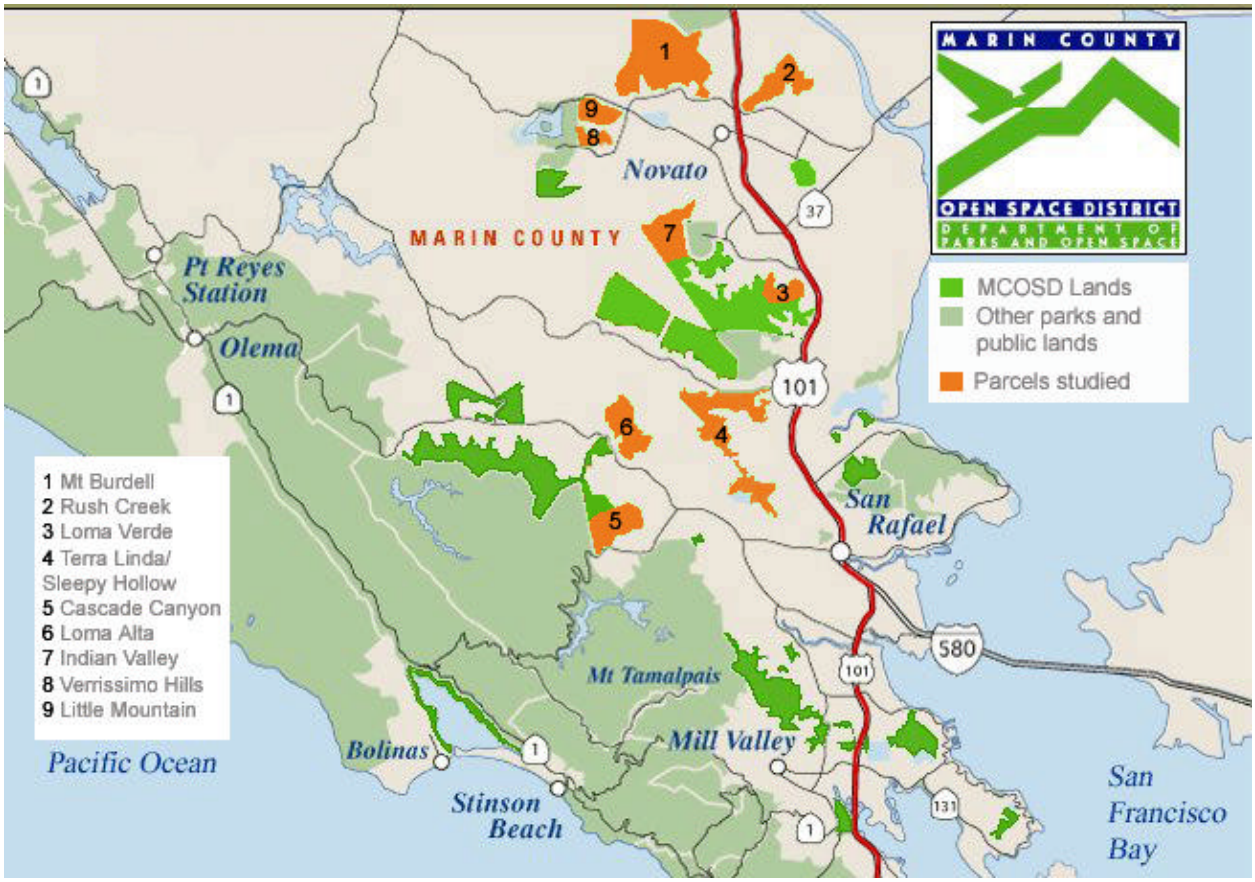

Figure 1. Map of site locations. The name and location of each parcel studied shown in the legend above.

Techniques of Analysis I used maps of the park on the Marin County Open Space District website (www.marinopenspace.org/home.asp) to count the number of entrance gates at each park. I measured the distance of each parcel from highway 101 by entering in the address of the entrance gate or parking lot closest to highway 101 into yahoo maps (http://maps.yahoo.com) and summing the distances of the roads from highway 101. I summed the total number of citations issued at each parcel over a four year time period from 2001-2005 to determine total recreational use intensity.

I used ArcGIS 9.1 to extract the five remaining site and landscape variables for each open space parcel (trail and fire road density, number of suburban, exurban, and rural parcels within 500 m of each preserve). I used the Marin Open Space fire roads and trails layers to sum the

total meters of each trail type and divided by the total area of the open space parcel to calculate fire road and trail densities. For the adjacent parcel analysis, I used the county parcel database to select all parcels within 500m of each preserve. Because all of the preserves I studied were in close proximity to one another, I selected a 500 meter radius surrounding each open space parcel to prevent sampling overlap between different open space preserves. I classified the suburban, exurban, and rural parcels based on relative zoning definitions of parcels. I defined suburban parcels as plots of land less than one acre, exurban parcels as plots of land greater than one acre and less than 20 and rural parcels as plots of land greater than 20 acres. I summed the total number of surrounding parcels within a 500m buffer in each size classification for each open space parcel to obtain my final value.

This study used the statistical program JMP 5.1 to conduct all of the statistical analyses. I began by conducting an exploratory analysis to look for correlations between the explanatory variables and recreational use intensity. I used a cube root transformation on trail density, total number of citations, and the number of suburban and exurban parcels within 500m, a square root transformation on fire road density and the number of entrance gates, a log transformation on the number of exurban parcels within 500m, and no transformation on the distance from highway 101. To identify the most important variables determining recreational use intensity, I used a multiple regression analysis incorporating all of the explanatory variables. I used a backwards, stepwise variable selection process, performed automatically by the statistical program, JMP 5.1 to select the final model. I used the program's default setting of a significance level of a = 0.10, as the criterion for an explanatory variable's entry or removal from the multiple regression model. Lastly, I used a linear regression analysis to test the correlation between the intensity of recreational use and carnivore population densities.

Results

For the exploratory analysis, linear regression results of this study show the number of suburban and exurban parcels within 500m was statistically significant and positively correlated with intensity of recreational use (Table 1). The distance off highway 101 showed a statistically insignificant, but weakly negative relationship with intensity of recreational use. All other landscape variables showed a statistically insignificant, but weakly positive relationship with intensity of recreational use.

Table 1. Exploratory data analysis. Parameter estimates for the linear regressions of the landscape variable terms and recreational use intensity. The number of suburban and exurban parcels within 500m each showed a positive, statistically significant relationship with intensity of recreational use.

Term	**Coefficient**	**SE**	**X^2**	**p**	**R^2**
Trail density	246.93	201.53	1.5013	0.2485	0.131
Fire road density	2990.8	1754.2	2.90	0.119	0.225
Number of entrance gates	0.8443	0.5721	2.178	0.171	0.179
Distance from highway 101	-0.1198	0.358	0.112	0.745	0.011
Number of suburban parcels within 500m	0.4040	0.1480	7.449	0.0212	0.427
Number of exurban parcels within 500m	1.8833	0.5808	10.513	0.0088	0.512
Number of rural parcels within 500m	0.7401	1.503	0.2425	0.6330	0.024

For the multiple regression analysis, the final model selected shows that trail density and the number of suburban parcels within 500m of each open space parcel are positively correlated with recreational use intensity. The final multiple regression, backwards stepwise model showed an r square value of 0.633 and an r square adjusted value of 0.551 with both landscape variables significant at $p < 0.05$ (Table 2).

Table 2. Multiple regression model of site and landscape correlates of recreational use intensity. Parameter estimates for the backwards stepwise logistic models testing all variables. Both landscape variables selected in the final model are statistically significant at $p < 0.05$. Trail density and the number of suburban parcels within 500m are positively correlated with intensity of recreational use. The r square adjusted of the whole model is 0.551.

Term	**Coefficient**	**SE**	**X^2**	**p**
Intercept	-3.2414	1.5053	7.745	0.0597
Trail density	312.76	139.38	5.036	0.0515
Number of suburban parcels within 500m	0.4422	0.1261	12.293	0.0067

For the linear regression of recreational use intensity and carnivore scat density there was a statistically insignificant, but weakly positive relationship (Fig. 2). The linear regression had an r squared value of 0.02 and a p value of 0.68.

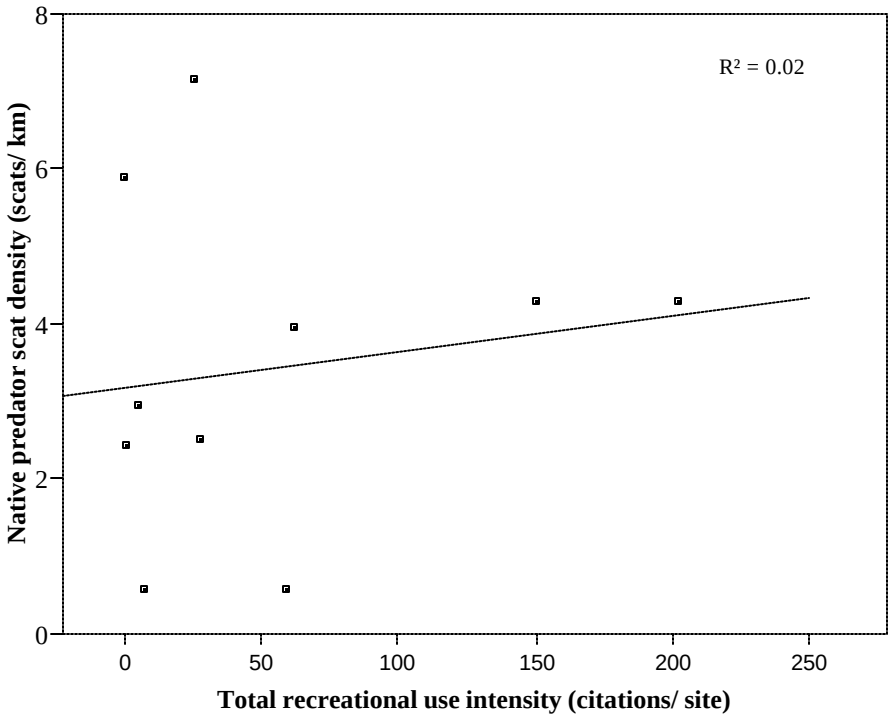

Figure 2. Relationship between carnivore scat density and recreational use intensity. This figure shows a statistically insignificant, but weakly positive relationship between intensity of recreational use (total number of citations issued from 2001-2005 per open space parcels) and native predator scat densities (scats per km of transect surveyed).

Discussion

The results of this study have important implications in public and or private lands where the long term coexistence of wildlife and recreation is a fundamental goal. These results suggest that trail density and the number of suburban parcels within 500m of an open space parcel are important factors in determining the intensity of recreational use for a particular preserve. In order to decrease current intensity of recreational use for an individual protected area, managers could decrease flexible landscape variables by closing off certain trails.

While the number of suburban parcels surrounding open space preserves is fixed for existing preserves, conservation planners and developers can control this variable in the future. Therefore, in undeveloped areas surrounding open space parcels, zoning plans can contribute to controlling the intensity of recreational use based on the size and number of private parcels surrounding the protected area. Managers may restrict human activity and minimize potential impacts on wildlife in protected areas by creating buffer zones (Fernandez at al. 2005).

The statistically significant relationship between surrounding suburban development and recreational use intensity suggests that a significant amount of the intensity of recreational use is caused by local, surrounding communities. This relationship may help explain the insignificant relationship between the distance of the preserve from highway 101 and recreational use intensity. Therefore, if the open space parcels are accessed more by surrounding local communities rather than by visitors, open space parcels closer to highway 101 may not have a greater recreational use intensity simply because most recreators accessing the park are within walking distance.

While surrounding exurban development was not selected in the final, multiple regression analysis, it did show a statistically significant, positive relationship with intensity of recreational use in the exploratory analysis and therefore may be an important indicator of recreational use intensity.

Furthermore, although this study did not find a statistically significant relationship between recreational use intensity and carnivore population densities, this may be due the relatively small sample size of the open space parcels studied. For future studies, an increase in the number of sites tested for recreational use intensity may result in a statistically significant relationship.

Another constraint of this study is the citation data that was used an indicator of intensity of recreational use. While all open space parcels in this study permit recreation and are managed by the same organization, Marin County Open Space District, other surrounding preserves are not patrolled at all and thus no citations are issued for these parcels. Therefore, variation in the number of citations issued may be due to variation in the frequency of patrol of a particular site. However, this study is not interpreting the amount of citations as an absolute truth to the intensity of recreational use. Thus more accurate measurements of recreational use intensity such as an in depth, replicated survey should be considered for future studies to provide more valid results and conclusions.

This study focused specifically on the relationship between seven landscape variables, intensity of recreational use and carnivore population densities; however, there may be several other important factors contributing to recreational use intensity and its negative impact on wildlife. Factors such as reserve size, local human density, the type of recreation, and trail patterns may play an important role in the intensity of recreational use and the negative impact on carnivores in the preserves (Parks and Harcourt 2002; Taylor and Knight 2003)

This study suggests that managers and developers work together to plan the location of preserves and the surrounding development to minimize negative impact from recreation without unnecessarily hindering development. In order to promote the long term survival of carnivores and other wildlife, human disturbance must be constrained within the species' tolerance or resilience threshold (Weaver et al., 1996). Thus managers and developers can more specifically tailor both management and development depending on the wildlife within the preserve. Understanding recreational use indicators and potential impacts on wildlife provides useful insight for current and future management and protection.

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