Landscape and Urban Planning 175 (2018) 62–71

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Research Paper

Accessibility drives species exposure to recreation in a fragmented urban reserve network

Courtney L. Larson[a,*], Sarah E. Reed[a,b], Adina M. Merenlender[c], Kevin R. Crooks[a]

[a] Department of Fish, Wildlife, and Conservation Biology, Colorado State University, Fort Collins, CO 80523, USA
[b] North America Program, Wildlife Conservation Society, Bozeman, MT USA
[c] Department of Environmental Science, Policy, and Management, University of California, Berkeley, CA, USA

ARTICLE INFO

Keywords:
Recreation
Protected areas
Visitation
Disturbance
Species exposure

ABSTRACT

Outdoor recreation is a valuable ecosystem service permitted in most protected areas globally. Land-use planners and managers are often responsible for providing access to natural areas for recreation while avoiding environmental impacts such as declines of threatened species. Since recreation can have harmful effects on biodiversity, reliable information about protected-area visitation patterns is vital for managers. Our goal was to quantify recreational use in a fragmented urban reserve network and identify factors that influenced visitation. We empirically measured visitation rates at 18 reserves in San Diego County, California. Using random forest models, we identified biophysical and socioeconomic factors that influenced spatial variation in visitation rates and made projections to 27 additional reserves, validating with an expert opinion survey. Visitation rates varied widely across the reserve network. Accessibility variables, such as numbers of housing units and parking lots, were key explanatory variables that had positive relationships with visitation rates. To illustrate the applications of our models, we assessed the exposure of 7 species and subspecies of conservation concern to recreation by comparing predicted occurrence to projected visitation intensities. We found that several species and subspecies, including the orange-throated whiptail (*Aspidoscelis hyperythra*), western spadefoot (*Spea hammondii*), and the federally-threatened coastal California gnatcatcher (*Polioptila californica californica*), are likely exposed to high levels of recreational activity. Our results can be used to identify species for further research, highlight areas with potential conflict between recreation and conservation objectives, and forecast future changes in visitation.

1. Introduction

Outdoor recreation is a valuable cultural ecosystem service (Bergstrom & Cordell, 1991; Chan et al., 2012), providing important benefits for human health and well-being, local economies, and human livelihoods (Cisneros-Montemayor & Sumaila, 2010; Ekkel & de Vries, 2017). Globally, protected areas receive an estimated 8 billion visits per year (Balmford et al., 2015). In the United States, total visitor days increased by 32.5% from 2000 to 2009, and growth is expected to continue until at least 2060 (Cordell, 2012). Publicly-owned protected lands designated for conservation are open to recreation in most cases, including 94% of IUCN protected areas (Eagles, McCool, & Haynes, 2002; IUCN & UNEP, 2014). Land-use planners and managers are often responsible for providing access to natural areas for a wide variety of outdoor recreation activities while avoiding environmental impacts such as further declines of threatened species.

However, a growing body of research demonstrates that recreation can have various damaging effects on animals (Barros, Monz, & Pickering, 2014; Larson, Reed, Merenlender, & Crooks, 2016; Monz, Pickering, & Hadwen, 2013; Sato, Wood, & Lindenmayer, 2013), including increased physiological stress (Arlettaz et al., 2007), reduced reproductive success (Beale & Monaghan, 2005), declines in abundance and occurrence (Reed & Merenlender, 2008), modified habitat use (George & Crooks, 2006), and altered species richness and community composition (Kangas, Luoto, Ihantola, Tomppo, & Siikamäki, 2010). These effects are widespread, as recreation activity is listed as a threat to birds in 65% of the world's biodiversity hotspots (Steven & Castley, 2013), and a recent review found that 93% of published studies documented at least one effect of recreation on animal species (Larson et al., 2016). The dual missions of protected lands create a dilemma for land-use planners and managers who must balance the growing demand for outdoor recreation with the protection of natural resources.

To best accommodate increased demand for outdoor recreation and manage potential effects on species, managers need reliable information about protected-area visitation patterns (McClaran & Cole, 1993). Measures such as the total number and the spatial and temporal

* Corresponding author.
E-mail addresses: courtney.larson@colostate.edu (C.L. Larson), sreed@wcs.org (S.E. Reed), adinam@berkeley.edu (A.M. Merenlender), kevin.crooks@colostate.edu (K.R. Crooks).

https://doi.org/10.1016/j.landurbplan.2018.03.009
Received 10 May 2017; Received in revised form 9 March 2018; Accepted 12 March 2018

distribution of visitors participating in different recreation activities can help managers understand and mitigate potential impacts on ecological communities by identifying areas of particularly high use, re-orienting trail networks, allocating staff, and monitoring compliance with regulations (Cessford & Muhar, 2003; Hadwen, Hill, & Pickering, 2007). In addition, understanding the drivers of reserve visitation can help predict human activity at other reserves, make projections about the effects of future changes in the reserve network (e.g., addition of new reserves, construction of trails or parking lots), and inform reserve design and land management. However, visitation data is often sparse or non-existent despite the importance of understanding how, where, and when impacts of recreation on animals are occurring (Becken & Job, 2014), especially at the landscape level where monitoring efforts are rare (Braunisch, Patthey, & Arlettaz, 2011; Monz, Cole, Leung, & Marion, 2010; Rösner, Mussard-Forster, Lorenc, & Müller, 2014).

Here, we quantify spatial and temporal variability in recreation across a fragmented urban reserve network in San Diego County, California, where protections have been established for threatened species under a Multiple Species Conservation Program (MSCP) developed under Section 10 of the United States Endangered Species Act (U.S. Fish and Wildlife Service & National Marine Fisheries Service, 1996). We measured visitation using counts from remotely-triggered cameras and tested how visitation rates (visits/day) and intensity (visits/hectare/day) varied with reserve characteristics (e.g., reserve area, range in slope), accessibility (e.g., number of parking lots), and substitution factors (e.g., number of similar reserves within a 10 minute travel time). We then applied the models to estimate visitation at 27 additional reserves. We also surveyed reserve managers and staff, who are knowledgeable about how these areas are used, and used their answers to validate the model projections. As an illustration of how these models could be applied to help balance recreation and conservation goals in protected areas, we then examined the exposure to recreation of 7 species and subspecies of conservation concern. Since little is known about the effects of recreation on these species, developing landscape-scale recreation intensity models and comparing where recreational use overlaps with likely species occurrences can help set priorities for further study on those that are currently exposed to high levels of recreation and identify locations for potential management actions.

2. Methods

2.1. Study site

San Diego County, California has a large human population and high levels of biodiversity and endangerment. It is the fifth most populous county in the United States with over 3.2 million residents (U.S. Census Bureau, 2016). Coastal southern California is a hotspot of global biodiversity that is home to over 500 vertebrate species (Myers, Mittermeier, Mittermeier, da Fonseca, & Kent, 2000) and contains large numbers of rare or threatened plants and animals (Crain & White, 2013; Dobson, Rodriguez, Roberts, & Wilcove, 1997). San Diego's MSCP, designed to protect 85 plant and animal species, was one of the first multiple species Habitat Conservation Plans developed under the United States Endangered Species Act (CA Department of Fish and Game, 2012). The MSCP establishes a comprehensive habitat conservation framework and allows the issuance of permits for incidental take of threatened and endangered species. San Diego County's MSCP reserves are managed by a variety of city, county, and state agencies, most of which have a mission statement that encompasses both human use and natural resource protection. Notably, the MSCP itself includes "access to natural preserves for passive recreation" as one of its objectives (MSCP Policy Committee and MSCP Working Group, 1998). MSCP reserves vary in size, distance from urbanized areas, and the expected intensity of recreational use. This gradient in recreational use presents a natural experiment over which recreational activity and exposure of wildlife can be measured and compared.

2.2. Reserve selection

Local biologists and reserve managers aided our selection of 18 reserves for field study ("sampled reserves") along an expected gradient of recreation activity based on distance from densely-populated areas and anecdotal reports of use. We selected an additional 27 unsampled reserves dispersed over a larger spatial extent than the sampled reserves; however, we did not include reserves that were 2 or more standard deviations away from the mean value from the sampled reserves for 4 or more of the explanatory variables (Table 1; Appendix A). All reserves were publicly owned, part of the MSCP, and least 100 ha in area. This size threshold has been used as a minimum size designation for core conservation areas (Wade & Theobald, 2010), and many of the smaller reserves in San Diego County are heavily landscaped neighborhood parks unlikely to support populations of sensitive species. Seven reserves were closed to the public (two sampled and five unsampled reserves).

2.3. Field data collection

At each sampled reserve, we identified all official entrances and stratified them into three categories: staging areas (primary access points with parking lots), trailheads (entrances depicted on reserve maps and accessible by car, often with street parking), and connectors (entrances typically used to enter from an adjacent neighborhood or reserve). At closed reserves, we assumed that service roads that intersected the reserve boundary would be the most likely entry points for unauthorized use. Unofficial (typically user-created) entrances were common but difficult to locate systematically and were not included in the sampling design; however, based on our trail digitization effort we estimate that unofficial trails comprise up to 45% of the total trail network.

We used remotely-triggered cameras (Bushnell TrophyCam) to document human activity at reserve entrances from July to October 2013. We installed cameras at all staging areas and trailheads and a random sample of at least 50% of connectors, except for one reserve (Mission Trails) with an unusually large number of entrances. In total, we installed cameras for at least 14 days at 83 entrances across the 18 reserves. Cameras captured a single photo at each trigger and took a maximum of one photo every ten seconds.

2.4. Visitation estimates

We randomly truncated the beginning or end of each sampling period to obtain 14-day periods for analysis. For cameras that recorded more than 2000 photos during the sampling period ($n = 22$), we randomly subsampled the data to reduce time spent sorting photos. We viewed each photo and counted the number of hikers, bicyclists, and people riding or leading horses ("equestrians"). We also recorded the direction of travel to quantify visitors entering versus exiting the reserve. Imbalance in counts by direction was likely attributable to camera trigger speed (e.g., failing to capture bicyclists going downhill due to their speed), or to visitors entering and exiting through different entrances. For each reserve, we combined detections of hikers, bicyclists, and equestrians and the directional imbalance to create reserve-level empirical estimates of the number of visits per day (henceforth: visitation rate) and visitation intensity (visits/hectare/day). We calculated separate estimates of visitation rates and intensity by hikers, bicyclists, and equestrians for each reserve. For details of these calculations, see Appendix B.

We also conducted an online survey (SurveyGizmo, Widgix, LLC) of rangers and reserve staff to systematically collect expert opinion data on visitation patterns to use as a validation dataset for the 27 reserves at which we did not collect field data. The survey was open from May to