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The influence of periodic increases of human activity on crepuscular and nocturnal mammals: Testing the weekend effect

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A B S T R A C T

Human recreation can negatively affect wildlife, particularly on weekends when human activity is highest (i.e., the weekend effect). Much of what we understand about the weekend effect is based on research conducted on diurnal species, which have greater temporal overlap with humans. Because nocturnal species generally avoid times when humans are active, they are likely less affected by anthropogenic activity on weekends. Our objective was to test the weekend effect in relation to the degree of nocturnality of mammals in a recreational area. We predicted that as nocturnality increased, the effect of human activity would decrease. To address our objective, we placed 50 remote cameras along the Diamond Fork River in Utah from January to June 2015. We found that three out of the four focal species supported our predictions. Mule deer (crepuscular) reduced activity throughout our entire study area during weekends and avoided campgrounds. Beavers and mountain lions (both nocturnal) did not negatively respond to increased human activity. Raccoons (nocturnal) reduced activity during weekends, but only within campground areas. Our findings indicate that as the temporal overlap increases between wildlife and humans, so does the influence that humans have on wildlife.

1. Introduction

Human recreation has become a threat to many species of wildlife (Benitez-Lopez et al., 2010; Larson et al., 2016). Increasing human populations will likely lead to higher frequencies of recreational activities, resulting in increased interactions with wildlife (Martineau et al., 2016; Marzano and Dandy, 2012). Human-wildlife interactions can alter wildlife behavior, which can lead to increased stress levels, missed foraging opportunities, reduced reproductive success, avoidance of certain habitats, and increased mortality (Longshore et al., 2013; Martin and Réale, 2008). Mitigating and managing the potential negative effects resulting from human-wildlife interactions will be a continual challenge for wildlife conservation and human recreation as populations of humans increase and encroach on wildlife habitat (Krausman et al., 2008).

Outdoor recreational areas near urban settings are ideal locations for testing human-wildlife interactions (Ladle et al., 2016; Ruhlen et al., 2003). Recreational areas near cities are likely to experience the greatest increase in human activity because of proximity and convenience, due to both distance and well developed road networks that enhance ease of access. Yet, increases in human activity are likely periodic in nature, most commonly occurring during weekends (Ladle et al., 2016; Longshore et al., 2013; Ruhlen et al., 2003). Due to the influence that humans have on wildlife (Kays et al., 2016; Martineau et al., 2016; van Doormaal et al., 2015), behavior of wildlife may differ between "busy" weekend periods and relatively "quiet" weekday periods (i.e., the weekend effect; Lafferty, 2001; Longshore et al., 2013; Stalmaster and Kaiser, 1998). However, the weekend effect may differentially affect diurnal and nocturnal wildlife based on contrasting patterns of activity relative to human activity.

Diurnal species may be particularly sensitive to increased activity of humans on weekends due to greater temporal overlap with humans (Longshore et al., 2013; Roy et al., 2014), whereas nocturnal species may avoid periods when humans are most active. The majority of research that has evaluated support for the weekend effect hypothesis has primarily focused on diurnal species (Stalmaster and Kaiser, 1998; Tadesse and Kotler, 2012; Tarjuelo et al., 2015), with much less attention towards crepuscular and nocturnal species. While most of the studies on diurnal species support the weekend effect, the general applicability of this hypothesis to crepuscular and nocturnal species is not as clear. For example, when human activity was high on weekends, some crepuscular and nocturnal species were less active while others became more active (Barrueto et al., 2014; Carrillo and Vaughan, 1993; Jacobson and Lopez, 1994). Given the continual increase of the global human footprint (Venter et al., 2016), developing a better understanding of the periodic influence that humans may have on the

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behavior of crepuscular and nocturnal wildlife will allow us to better manage the shared use of recreational areas (Kays et al., 2016; Young et al., 2005).

Our objective was to test the weekend effect hypothesis in relation to the degree of nocturnality of mammals in a recreational area near a city. Although humans are primarily diurnal, their activities in recreation areas can also be crepuscular. Therefore, we predicted that temporal overlap with humans would cause crepuscular species to decrease in activity on weekends, particularly in campground areas where human activity is concentrated. Alternatively, nocturnal species have little to no temporal overlap with humans. Thus, we predicted that nocturnal species would not reduce activity in response to increased human activity during weekends (Barrueto et al., 2014; van Doormaal et al., 2015). To test our predictions, we used remote cameras to monitor a recreational area where humans, crepuscular, and nocturnal mammals were common. We then evaluated diel (daily) activity patterns of mammalian wildlife and quantified their activity levels in response to changes in levels of human activity.

2. Methods

2.1. Study area

We conducted this study along the Diamond Fork River located in the Wasatch Mountain Range in central Utah (40° 1′42.04″ N 111° 30′3.70″ W). The Diamond Fork area is a popular location among recreationists because it offers a variety of activities year-round (e.g., fishing, camping, hunting, hiking, etc.) and is relatively close to urban areas (12 km from nearest city). Diamond Fork is located within a small canyon, branching off from the larger Spanish Fork Canyon. Vegetation characteristics of the Diamond Fork area included maple (*Acer* spp.), oak (*Quercus* spp.), juniper (*Juniperus* spp.), serviceberry (*Amelanchier alnifolia*), aspen (*Populus tremuloides*), and cliffrose (*Purshia stansburiana*). Elevation across our study area ranged from 1514 to 1609 m. Temperatures during our study ranged from −13.1 to 32.2 °C (mean temperature of 7.9 °C). During our study, there was a total of 15.13 cm of precipitation (MesoWest, Bureau of Land Management & Boise Interagency Fire Center).

2.2. Data collection

From January to June 2015, we placed 50 Reconyx PC900 cameras (Reconyx, Inc., Holmen, WI) along 12 km of the Diamond Fork River (spaced approximately every 250 m). We positioned cameras approximately 40 cm off the ground and attached them to metal posts. Each camera was programmed to record two photographs per trigger with a 30 s quiet period. We checked cameras every two weeks to perform camera maintenance (if needed) and to remove any obstructions (e.g., vegetation) from the camera's view.

We used Exifer v.2.1.5 (www.friedemann-schmidt.com/software/exifer) to extract file paths and date/time stamps from each image. We then created a Microsoft Access database for photo identification with the file paths and date/time information for each image. We classified animals in the photographs to the species level. After photo identification, we compiled species photo sequences into independent visit events separated by 30 min (Hall et al., 2016). All other photographs that occurred within the same visit were consolidated to a single visit. We determined the diel activity patterns of each species by using the time associated with each visit and categorized each species as crepuscular or nocturnal based on their diel activity.

To account for differences in vegetation characteristics between sites, we used Landscape Fire and Resource Management Planning Tools (LANDFIRE) data provided by the U.S. Department of Agriculture Forest Service and the U.S. Department of the Interior. LANDFIRE is a vegetation classification derived from LANDSAT imagery with a spatial resolution of 30 m. Vegetation height was defined as vegetation 0–0.5 m, 0.5–1 m, 1–3 m, shrubs above 3 m, Trees 5–10 m, Trees 10–25 m, and sparse vegetation using LANDFIRE data. With this information, we were able to define the dominant vegetation height within each individual site (defined as within 30 m of the camera location).

2.3. Statistical analysis

We used a Kruskal-Wallis and a Dunn's post hoc test to determine if there were differences in anthropogenic activity between weekdays and weekends. We defined "weekdays" as Monday through Thursday and "weekends" as Friday through Sunday (Barrueto et al., 2014; Moore and Seigel, 2006; Ruhlen et al., 2003) with the exception of three Mondays due to national holidays resulting in uncharacteristic long weekends (Ladle et al., 2016). To account for the overnight presence of humans in designated camping areas, we included a binary "campground" covariate. "Campground" sites were considered a categorical covariate (0 = non-campground, 1 = campground) and consisted of sites S00–S20 (approximately 40% of our study area) as these camera locations were found within the designated camping areas of a national forest campground.

We used a two-stage modelling approach to determine if increased human activity on weekends influenced mammalian wildlife (Morrison et al., 2014). Given our zero-heavy data (characteristic of camera trapping studies), we used generalized linear mixed models with a zero-inflated distribution. In stage one, we determined the best environmental variables to use for each species at each camera location. We evaluated environmental variables such as vegetation height, daily temperature (maximum, minimum, and average), and the percentage of moonlight emitted during nighttime hours (to account for potential differences on activity of nocturnal species during moonlit nights). We also added camera location and Julian day as random effects to help account for re-sampling occurring at the same sites across days (Ladle et al., 2016). Using AIC model selection, we evaluated model performance and ranked competing models using AICc values and model weights (Burnham and Anderson, 2002). We considered models to be competing if they were within 2.0 ΔAICc of each other.

In stage two, we created baseline and main effect models. Based on the varying quantities of human photos, depending on the day of the week, we categorized the days as either weekday or weekend and used this as our main effect variable. These categories corresponded to "low" (weekday) and "high" (weekend) human activity (George and Crooks, 2006; Ladle et al., 2016; Longshore et al., 2013). Our baseline habitat/environmental model consisted of precipitation and the most competitive vegetation and temperature variables from stage one (see Tables 1 and 2) (Morrison et al., 2014). We then created main effect models that were identical to the baseline model, except that they included weekend, campground, and weekend*campground (to account for the potential interaction of high human activity in campgrounds on weekends) variables. For mammals that are generally considered prey (e.g., mule deer [*Odocoileus hemionus*]), we included the occurrence (number of photos/day) of carnivores (coyotes [*Canis latrans*], bobcats [*Lynx rufus*], and mountain lions [*Puma concolor*]) as covariates to account for potential behavioral changes due to presence of predators (Berger, 2007; Krishna et al., 2016). We then performed model selection to determine top models for mammalian wildlife following the same evaluation criteria from stage one. We averaged competing top models within 2.0 ΔAICc to acquire beta coefficients. This approach allowed us to compare the relative importance of the weekend effect on the activity of mammals after controlling for environmental factors. We used R package "glmmADMB" to run linear mixed effects models (http://glmmadmb.r-forge.r-project.org/). To test for the occurrence of spatial autocorrelation (i.e., lack of independence) between cameras we used Moran's *I* spatial autocorrelation analyses in ArcGIS Pro (version 1.4, Environmental Systems Research Institute, Redlands, CA).