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Spatial and temporal response of wildlife to recreational activities in the San Francisco Bay ecoregion

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ABSTRACT

Non-motorized human recreation may displace animals from otherwise suitable habitat; in addition, animals may alter their activity patterns to reduce (or increase) interactions with recreationists. We investigated how hiking, mountain biking, equestrians, and recreationists with domestic dogs affected habitat use and diel activity patterns of ten species of medium and large-sized mammals in the San Francisco Bay ecoregion. We used camera traps to quantify habitat use and activity patterns of wild mammals and human recreationists at 241 locations in 87 protected areas. We modeled habitat use with a multi-species occupancy model. Species habitat use was most closely associated with environmental covariates such as landcover, precipitation, and elevation. Although recreation had less influence on habitat use, the presence of domestic dogs was negatively associated with habitat use of mountain lions and Virginia opossum. We also compared diel activity patterns of species at sites with no observed recreation to the activity patterns of species at sites with high (≥eight per day) levels of non-motorized recreation. Coyotes were more active at night and less active during the day in areas with high levels of recreation. Striped skunks were slightly more active later into the morning in areas that allowed human recreation. Smaller carnivores with nocturnal activity patterns may not be directly affected by recreational activities that are limited to daylight hours. We suggest that by maintaining habitat free of domestic dogs, and creating trail-free buffers, land managers can manage recreation in a way that minimizes impacts to wildlife habitat and preserves the value of protected areas to people and wildlife.

1. Introduction

Managers of many parks and protected areas seek to protect natural resources while simultaneously providing opportunities for non-motorized recreation. Non-motorized recreation by humans, and associated domestic animals such as dogs and horses, can impact wildlife by disrupting normal maintenance routines (Sime, 1999; Lenth et al., 2008), reducing feeding times (Cassirer et al., 1992), displacing them from suitable habitat (Papouchis et al., 2001; Lenth et al., 2008), increasing adrenal stress hormones (Barja et al., 2007), and provoking flight responses (Taylor and Knight, 2003). Wildlife species can respond by avoiding (sensitive species) or seeking areas of human activity (human-associated species) (Frid and Dill, 2002; Tigas et al., 2002; Reed and Merenlender, 2008). In coastal southern California, Ordeñana et al. (2010) found coyote (*Canis latrans*) and raccoon (*Procyon lotor*) occurrences increased, and bobcat (*Lynx rufus*), grey fox (*Urocyon cinereoargenteus*), and mountain lion (*Puma concolor*) occurrences decreased, with both proximity to and intensity of urbanization. Bighorn sheep (*Ovis canadensis*) avoid habitat with human activity in Canyonlands National Park, Utah (Papouchis et al., 2001) and the development of an extensive trail network used by many hikers and domestic dogs is thought to be the major factor in the extirpation of desert bighorn sheep from the Santa Catalina Mountains, Arizona (Krausman et al., 1995a,b).

In addition to altering habitat use and wildlife abundance, human activities can also change animal activity patterns. For example, artificial night lighting altered the activity patterns of wallabies in a way that disrupted the population's breeding synchrony (Robert et al., 2015). However, remarkably little research has attempted to document whether non-motorized human recreation alters animal activity patterns (but see Wang et al., 2015).

Because of its 7.5 million human residents (U.S. Census Bureau 2014), 4800 km^2 (1.2 million acres) of open space (BAOSC, 2011), and diversity of protected area management agendas, the San Francisco Bay Area is an ideal laboratory to study impacts of non-motorized recreation on wildlife. In one such study of recreation impacts in Bay Area oak woodlands, coyote and bobcat scat densities were more than five times lower in 14 Bay Area protected areas that permitted non-motorized

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recreation than in 14 paired protected areas that did not (Reed and Merenlender, 2008). However, use of carnivore scats as a proxy for carnivore population size is problematic because domestic dogs accompanying human recreationists can consume and disturb scat of bobcats and coyotes, decreasing detection probabilities and likely lead to underestimation of carnivore populations.

Camera traps are an efficient tool for detecting medium and large-sized terrestrial mammals (Tobler et al., 2008) and have been widely used to study their occupancy and habitat use (e.g. Linkie et al., 2007; Tobler et al., 2009; Ahumada et al., 2013). Camera traps were three times more likely to detect coyote, striped skunk, cottontail, and raccoon than hair traps or track plates in a coastal ecosystem (O'Connell et al., 2006) and we believe that they provide better estimates of recreational activity and habitat use by a broad array of medium to large-sized mammals in our study area compared to other methods. We used camera traps to estimate numbers and activity patterns of ten mammal species (mule deer, mountain lions, coyote, bobcat, raccoon, grey fox, opossum, striped skunk, rabbit, feral pigs) and hikers, cyclists, equestrians, and recreationists with dogs in eight counties of the SF Bay Area. Based on results from previous studies, we expected species' response to human recreation to vary by species and type of recreation (Crooks, 2002; Wang et al., 2015; Wilmers et al., 2013).

Land managers face pressure to create trails and accommodate more users (Dolton-Thorton, 2015; M. Savidge, Golden Gate National Recreation Area, pers. comm., April 21, 2015). The goal of our study was to provide land managers with information that can help them manage recreation in a way that minimizes impacts to wildlife habitat and preserves the value of protected areas to people and wildlife. Results could also assist in the planning and management of wildlife corridors. Our specific objectives were to 1) quantify how non-motorized recreation (hiking, cycling, horse-riding, and dog-walking) affects occupancy for ten species of mammals (accounting for environmental variables), 2) determine if non-motorized recreation is associated with shifts in activities patterns of wildlife, and 3) describe temporal patterns of non-motorized recreation in protected areas in the San Francisco Bay area.

2. Methods

2.1. Study area

This study was carried out in the San Francisco Bay Area (Fig. 1). This region has a Mediterranean climate with numerous microclimates (NOAA, 1995). Cool marine air and persistent coastal fog keep temperatures along the coast 10–21 °C year-round (National Oceanic and Atmospheric Association, 1995). Inland temperatures can reach 32 °C. The Bay Area is part of the California Floristic Province and a biodiversity hotspot (Bay Area Open Space Council, BAOSC, 2011). Our study area includes diverse plant communities. We studied wildlife and recreation in the Bay Area's four dominant woodland types (Bay Area Open Space Council, BAOSC, 2011), namely redwood forests, Douglas-fir forests, montane hardwood forests, oak savannas and woodlands.

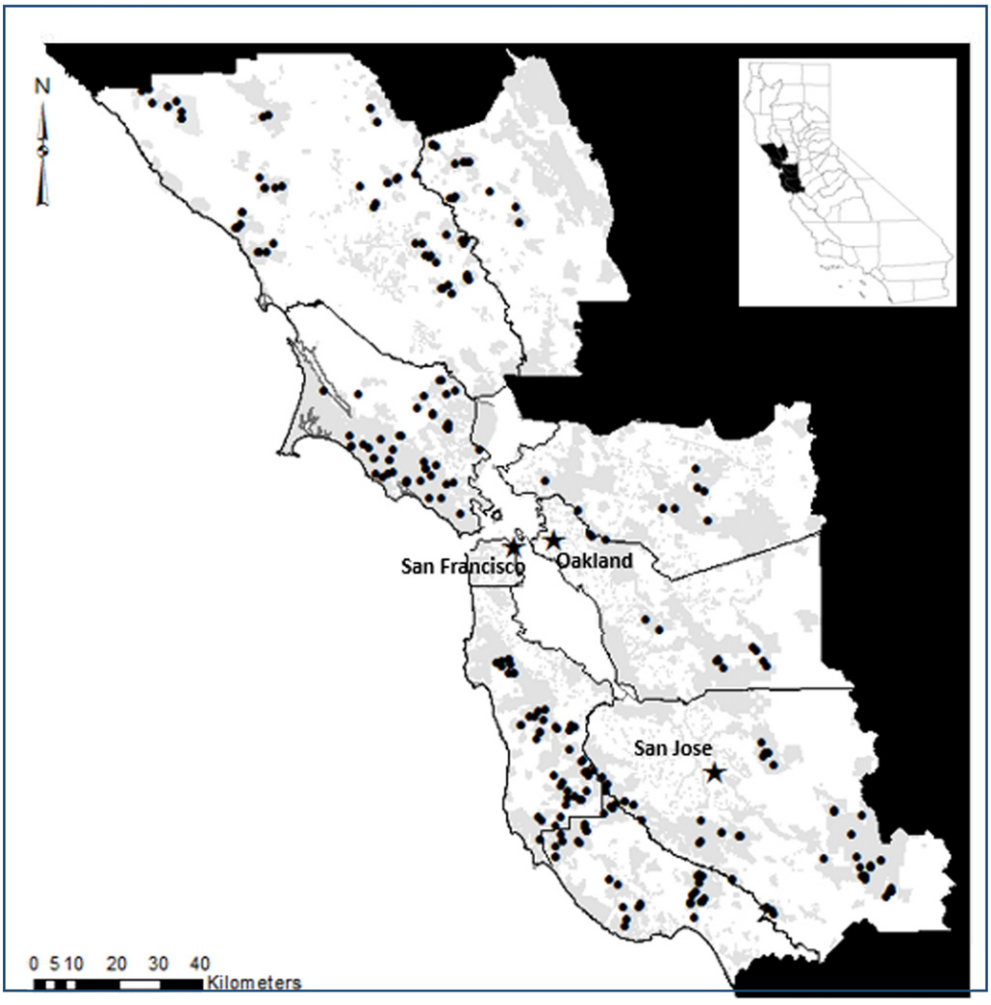

Fig. 1. Study area in the San Francisco Bay Area, including sites in Marin, Sonoma, Napa, Alameda, Contra Costa, Santa Clara, Santa Cruz, and San Mateo Counties. Location of sites sampled from 2011 to 2013 is denoted by black points. Grey shading in the background indicates protected areas designated in the California Protected Areas Database.