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Home in the heat: Dramatic seasonal variation in home range of desert golden eagles informs management for renewable energy development

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ABSTRACT

Renewable energy is expanding quickly with sometimes dramatic impacts to species and ecosystems. To understand the degree to which sensitive species may be impacted by renewable energy projects, it is informative to know how much space individuals use and how that space may overlap with planned development. We used global positioning system–global system for mobile communications (GPS-GSM) telemetry to measure year-round movements of golden eagles (*Aquila chrysaetos*) from the Mojave Desert of California, USA. We estimated monthly space use with adaptive local convex hulls to identify the temporal and spatial scales at which eagles may encounter renewable energy projects in the Desert Renewable Energy Conservation Plan area. Mean size of home ranges was lowest and least variable from November through January and greatest in February–March and May–August. These monthly home range patterns coincided with seasonal variation in breeding ecology, habitat associations, and temperature. The expanded home ranges in hot summer months included movements to cooler, prey-dense, mountainous areas characterized by forest, grasslands, and scrublands. Breeding-season home ranges (October–May) included more lowland semi-desert and rock vegetation. Overlap of eagle home ranges and focus areas for renewable energy development was greatest when eagle home ranges were smallest, during the breeding season. Golden eagles in the Mojave Desert used more space and a wider range of habitat types than expected and renewable energy projects could affect a larger section of the regional population than was previously thought.

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1. Introduction

Renewable energy development is occurring globally at a rapid pace (AWEA, 2013; EWEA, 2013). This process can have both positive and negative consequences to species and ecosystems (Katzner et al., 2013). For example, renewable energy development has the potential to reduce fossil fuel emissions and ameliorate global climate change and its effects on wildlife globally (AWEA, 2013; EWEA, 2013). However, renewable energy may also harm wildlife locally, most often directly via mortality (collision), or indirectly, through habitat alteration or through increased physiological costs due to behavioral responses (Katzner et al., 2013).

Managing the effects of renewable energy development on wildlife is improved by assessment of its potential impacts (Miller et al., 2014). When development is planned, overlap of its location with use of space by individual animals may be an important proxy to understand this risk. It is therefore important to understand space use by species potentially affected by renewable energy. The use of space by an animal changes over time, by age and by sex (Aebischer et al., 1993), and understanding these drivers can aid assessment of the impacts of development and for eventual mitigation of costs (Langston and Pulan, 2003; Marques et al., 2014).

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The Mojave Desert of southern California supports many renewable energy projects and the region is targeted for substantial increases in energy development. New development is needed to reach California's goal of providing 33% of retail electricity sales through renewable sources by 2020 (CA Senate Bill No. 2, 2011). To mitigate potential impacts of future renewable energy installations, the California Energy Commission, partnering with other government agencies, initiated the Desert Renewable Energy Conservation Plan (DRECP; CEC, 2014, 2011). This conservation plan is intended to identify areas well suited for energy development (Development Focus Areas or DFAs) and to identify areas of high biodiversity better suited for conservation.

The golden eagle (*Aquila chrysaetos*) is a primary target for conservation in the DRECP area (~91,406 km^2). A small population of breeding golden eagles nests within the DRECP (Latta and Thelander, 2013), and large numbers of eagles elsewhere have been affected both directly (killed; Smallwood and Thelander, 2008) and indirectly (Johnston et al., 2014) by renewable energy development. Eagles are long-lived species that produce few offspring and occur at low densities throughout their range (Watson, 2010); therefore, understanding potential impacts to these birds is a high priority for management agencies (USFWS, 2013).

We evaluated use of space by Mojave golden eagles as a proxy for risk (e.g., wind turbine blade strikes, solar flux or incineration, loss of foraging habitat, reduction in prey populations) from renewable energy development in and near the DRECP. We focused on 4 objectives to illuminate basic elements of golden eagle ecology and identify the temporal and spatial scales at which eagles may be affected by renewable energy. We (1) measured the size and monthly variation in size of golden eagle home ranges; (2) described extrinsic (vegetative class, elevation) and intrinsic (sex and age) characteristics of golden eagle monthly home ranges; and then (3) determined which biologically relevant extrinsic variables influenced temporal size patterns in home ranges. Finally, (4) we interpret these patterns in the context of planned renewable energy development within the DRECP.

2. Methods

2.1. Study area and focal species

We tracked eagles within the DRECP and surrounding Mojave Desert areas (for details see online Appendix A and Fig. B.1). Golden eagle nests in the Mojave Desert are sparsely distributed, with approximately 74 occupied territories in ~4.5 million hectares of public lands within the DRECP area (Latta and Thelander, 2013; see online Appendix A for details).

2.2. The Desert Renewable Energy Conservation Plan

The DRECP is designed to "provide for the protection and conservation of California desert ecosystems while providing streamlining of permitting for appropriate renewable energy projects" (CEC, 2011; www.drecp.org). It is intended to serve as a programmatic Habitat Conservation Plan under section 10 of the US Endangered Species Act (ESA), with coverage intended to include golden eagles and other species not otherwise listed under the ESA. The DRECP was developed by a group of collaborating agencies responsible for energy development and land management, including the California Energy Commission, the California Department of Fish and Wildlife, the U.S. Bureau of Land Management and the U.S. Fish and Wildlife Service. The plan identifies areas of high suitability for renewable energy (Renewable Energy Study Areas and DFAs) and areas of high conservation value that are less suited to renewable energy development (i.e., it identifies areas of avoidance for mitigation purposes; Marques et al., 2014). To minimize effects of renewable energy development and provide for the long-term conservation and management of species and their habitats, the DRECP aims to maximize conservation lands, maintain connectivity across the landscape, minimize edges, and represent the ecoregions, watersheds, and ecological communities across the environmental gradients of the desert region. Because of its adaptive nature, the draft DRECP identified a range of DFA alternatives that could meet the renewable energy needs of the state and the conservation needs of species and habitats managed by the cooperating agencies. The sizes and locations of renewable energy development varied among DFA alternatives of the DRECP. The agency version of the plan has been drafted; it is currently undergoing public review and is expected to become finalized in 2016.

2.3. Data collection

We captured and telemetered territorial golden eagles within the DRECP area (see online Appendix A for details on eagle selection and capture). Birds were outfitted with CTT-1070 global positioning system–global system for mobile communications (GPS-GSM) telemetry systems (Cellular Tracking Technologies, Somerset, PA, USA) attached as backpacks with a Teflon ribbon harness (Bally Ribbon Mills, Bally, PA) in an X configuration. These telemetry systems (<3% of body weight, per BBL standards) collect GPS data at 15-min intervals for 9 days and every 10th day at 30-s intervals and send them over the GSM network to data servers (Lanzone et al., 2012). We removed poor-quality GPS locations (i.e., 2D fixes and altitude above ground levels of <−50 m; Katzner et al., 2012) and, to be consistent in data analysis among days, we subsampled the 30-s data to 15-min intervals.

2.4. Data analysis

2.4.1. Home range and core range estimation

We estimated home ranges separately for each month of the two-year study period with adaptive Local Convex Hulls (aLoCoH; Getz et al., 2007) using package *adehabitatHR* (Calenge, 2006) within R (R Core Team, 2013). We used 95% and 50% isopleths to estimate overall monthly home range size (hereafter "home range") and monthly core home range size (hereafter "core range"), respectively (Getz et al., 2007; Kie et al., 2010; Powell, 2000; online Appendix A and Table A.1).

2.4.2. Extrinsic and intrinsic characteristics

Within the boundary of each monthly home range and core range we extracted GAP vegetation classes (USGS, 2011) and 10-m resolution elevation from the National Elevation Dataset (Gesch et al., 2002; ArcGIS 10.1, ESRI, Redlands CA). For our analysis, we used the four most common vegetation classes found in the study area (Forest & Woodland, Nonvascular & Sparse Vascular Rock Vegetation, Semi-desert, and Shrubland & Grassland) and combined all other classes that occurred with low frequency (Agriculture Vegetation, Aquatic Vegetation, Developed & Other Human Use, Open Water, and Recently Disturbed or Modified). We then calculated the proportion of area for each of the five classes in each monthly home range and core range.

We described the topographic characteristics of the home ranges and core ranges using three measurements. The first was the range of elevation (maximum–minimum elevation) within each home range. The second was a roughness ratio (DEM Surface Tools; Jenness, 2013) that accounts for areas with large (high values) or small (low values) amounts of topographic heterogeneity (online Appendix A). We used the standard deviation of