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Saving sage-grouse from the trees: A proactive solution to reducing a key threat to a candidate species

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ABSTRACT

Conservation investment in management of at-risk species can be less costly than a delay-and-repair approach implemented after species receive legal protection. The United States Endangered Species Act candidate species designation represents an opportunity to implement proactive management to avoid future listing. Such efforts require substantial investments, and the challenge becomes one of optimization of limited conservation funds to maximize return. Focusing on conifer encroachment threats to greater sage-grouse (*Centrocercus urophasianus*), we demonstrated an approach that links species demographics with attributes of conservation threats to inform targeting of investments. We mapped conifer stand characteristics using spatial wavelet analysis, and modeled lek activity as a function of conifer-related and additional lek site covariates using random forests. We applied modeling results to identify leks of high management potential and to estimate management costs. Results suggest sage-grouse incur population-level impacts at very low levels of encroachment, and leks were less likely to be active where smaller trees were dispersed. We estimated costs of prevention (treating active leks in jeopardy) and restoration (treating inactive leks with recolonization potential) management across the study area (2.5 million ha) at a total of US$17.5 million, which is within the scope of landscape-level conservation already implemented. An annual investment of US$8.75 million can potentially address encroachment issues near all known Oregon leks within the next decade. Investments in proactive conservation with public and private landowners can increase ecosystem health to benefit species conservation and sustainable land uses, replace top-down regulatory approaches, and prevent conservation reliance of at-risk species.

1. Introduction

Conservation biologists usually argue for a proactive approach to species conservation – making targeted investments before a species is endangered and under substantial risk of extinction (Drechsler et al., 2011; Benson, 2012; Polasky, 2012). But management to abate conservation threats can represent significant investments; globally, annual cost to reduce extinction risk of threatened species was estimated at US$76 billion (McCarthy et al., 2012), and in the U.S., annual cost to protect endangered species from two conservation threats was estimated at US$32 – 42 million (Wilcove and Chen, 1998). Consequently, sufficient action to abate threats starts only when species are under mandated statutory protection to prevent extinction, despite the fact that costs associated with such a reactive delay-and-repair policy may be higher than those of a proactive policy (Scott et al., 2010; Drechsler et al., 2011). Changing policies that direct species conservation from reactive to proactive processes will be one of the major challenges for the conservation community in the coming decades.

In the United States, the Endangered Species Act (ESA) of 1973 is considered as one of the world's strongest legislation providing protection for species of conservation concern (Czech and Krausman, 2001; Taylor et al., 2005; Schwartz, 2008; Harris et al., 2011). Like other conservation policies, the ESA is largely a reactive process. On the eve of its 40th anniversary, over 1400 wildlife and

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plant species were listed as threatened and endangered, and an additional 185 species were designated as candidate for listing (U.S. Fish and Wildlife Service (USFWS), 2013). Candidate status implies there is enough information to warrant protection under the ESA, but listing is precluded because other species are in greater conservation need and therefore receive a higher listing priority (Harris et al., 2011). While candidate species receive no immediate statutory protection, they can provide a unique opportunity to implement proactive management to avoid future listing and prevent them from becoming conservation-reliant species (i.e., requiring continued intervention to maintain viable populations; Scott et al., 2010; Goble et al., 2012).

The greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) is a year-round sagebrush (*Artemisia* spp.) community obligate whose populations have been declining primarily due to habitat loss and fragmentation, which prompted its candidate species designation in 2010 (USFWS, 2010). Key threats leading to sagebrush habitat loss and fragmentation include urbanization and energy development, conversion to croplands, invasion of exotic grasses, large-scale wildfires, and encroachment of conifer species (Knick et al., 2013a). It is estimated that as much as 90% of conifer encroachment in the western U.S. is occurring in sagebrush habitats (Davies et al., 2011; Miller et al., 2011). In its early stages (successional Phase I; Miller et al., 2005), conifer encroachment into sagebrush communities reduces shrub and herbaceous species diversity and increases bare ground (Knapp and Soulé, 1998; Miller et al., 2000). Overtime, trees become co-dominant (Phase II) resulting in the modification of community processes (Miller et al., 2005; Peterson and Stringham, 2008); sagebrush eventually lose vigor and decline in canopy cover, and conifers become the dominant species (Phase III; Miller et al., 2000; Knapp and Soulé, 1998). Miller et al. (2000) documented non-linear declines in sagebrush to approximately 20% of its maximum cover when conifers reached 50% canopy cover. Such losses of sagebrush habitat to conifer encroachment can be detrimental to sagebrush obligate wildlife species, especially those which are already of conservation concern such as the sage-grouse (Knick et al., 2013b; Rowland et al., 2006; Davies et al., 2011).

Previous studies have identified the negative effects of conifer encroachment on sage-grouse by empirically sampling characteristics of used sites (e.g., Freese, 2009; Casazza et al., 2011; Knick et al., 2013a), or by modeling habitat use using the percentage of conifer cover as a covariate (e.g., Doherty et al., 2008; Atamian et al., 2010; Doherty et al., 2010a; but see Casazza et al., 2011). However, there is large variability in stand characteristics as they relate to successional phases after stand establishment (Miller et al., 2005), and understanding how those characteristics affect sage-grouse demographics is essential to target proactive management that is already underway. Launched on the heels of the ESA candidate designation, the Sage Grouse Initiative (SGI) is a collaborative effort between federal and state agencies, non-governmental conservation organizations, and private landowners, to increase ecological understanding, identify critical management needs, and reduce threats to sage-grouse through proactive habitat management (Natural Resources Conservation Service (NRCS) 2013). The SGI implements habitat improvement programs that include acquisition of permanent conservation easements, promotion of sustainable grazing practices, and removal of encroaching conifers (NRCS, 2012), and in the first 2 years of its existence, SGI invested over US$92 million in sage-grouse habitat management. Given such large-scale investments and the immense conservation task at hand, it is important to target SGI's actions to maximize conservation return for every dollar spent.

In this paper we modeled sage-grouse demographics as a function of conifer stand characteristics in eastern Oregon. We demonstrated the application of such analyses to conservation planning by using modeling results to identify areas with high prevention and restoration management potential and to estimate the costs to apply such management. Overall we sought to better understand how conifer stand characteristics relate to sage-grouse demographics to provide guidance for the proactive conservation of this candidate species.

2. Materials and methods

2.1. Study area and lek activity

The study extent consisted of c. 2.5 million ha that were delineated by the NRCS as areas of high management potential and that overlapped current sage-grouse range (Fig. 1). The primary conifer species encroaching into sagebrush habitat in the study area was western juniper (*Juniperus occidentalis*; hereafter juniper), which exhibited geometric growth rates and expanded its range by as much as 600% in the last 150 years (Romme et al., 2009). We eroded (buffered inwards) the study boundaries by the largest scale for which we summarized covariates (5 km), and we included in the analyses data from leks, i.e., breeding sites where males congregate to display to females, that intersected the resulting polygons.

We modeled lek activity as the response variable using yearly peak male lek counts collected by the Oregon Department of Fish and Wildlife (ODFW). Lek activity is an important indicator of population-level impacts because up to 95% of nests are found within 10 km of leks (Holloran and Anderson, 2005; Doherty et al., 2010a; Hagen, 2011), and nest success is a vital rate influencing population growth (Taylor et al., 2012). Since 1996, the ODFW standardized counts as follows: (1) surveys were conducted three times each year during the breeding season (March 15–April 30), (2) lek complexes, defined as group of leks associated with a larger lek in close vicinity (<1.6 km), were completely surveyed in 1 day, (3) repeated lek surveys within a given year occurred at 7–10 day intervals, and (4) counts occurred during the first two hours after daybreak and under clear and calm weather conditions (Hagen, 2011). Following Hagen (2011), we defined leks as active if at least one male was counted within the last 7 years (2005–2011), and as inactive if no males were counted within the same period. Following consultation with ODFW personnel, we considered leks with missing data in the last 7 years as inactive ($n = 29$).

2.2. Conifer mapping and covariates

Spatial wavelet analysis (SWA) is an automated, object-based image analysis method used to map the location and structural properties of trees from high-resolution remotely sensed data (Falkowski et al., 2006; Strand et al., 2006). SWA performs well in characterizing juniper stands with <50% canopy closure (Falkowski et al., 2008; Smith et al., 2008), which is typical of early successional stages associated with conifer encroachment in our study area (Miller et al., 2005). We implemented SWA in program Matlab (2012) to map conifers from an NDVI image derived from 4-band National Agriculture Imagery Program imagery (2009–2010 at 1-m resolution). Specifically, we used a two-dimensional Mexican hat wavelet function and dilated it over a range of potential tree canopy diameters (0–15 m) in 0.1 m increments (Smith et al., 2008). We note that while SWA does not discriminate between juniper and other conifers or deciduous trees, the study area is dominated by western junipers therefore prevalence of other trees is relatively low and likely not to influence interpretation of results.

Because little information was available about the effects of conifer stand characteristics on sage-grouse and the spatial scale at which they operate, covariates were summarized at multiple