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Special Issue: Targeted Woodland Removal to Recover At-Risk Grouse and Their Sagebrush-Steppe and Prairie Ecosystems

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Introduction

Widespread degradation of sagebrush (*Artemisia* spp.) and prairie ecosystems in western North America (Noss et al., 1995; Samson et al., 2004) has resulted in the loss of ecosystem function and resilience (Chambers et al., 2016) and poses enormous conservation challenges. Threats vary in intensity across the region, but the most extensive top-down stressors impacting these shrub and grassland ecosystems include conversion of native rangelands to row crop agriculture, residential subdivision, energy, mining and other industrial developments, woodland expansion, type conversion from native vegetation to invasive species, and altered wildfire regimes (US Fish and Wildlife Service [USFWS] 2013). Newly signed land use plans are designed to guide future human infrastructure outside of Greater Sage-Grouse (*Centrocercus urophasianus;* hereafter "sage-grouse") and Lesser Prairie-Chicken (*Tympanuchus pallidicinctus;* "prairie-chicken") strongholds, and voluntary and incentive-based conservation actions help improve habitat quality (i.e., habitat restoration) and reduce habitat loss (e.g., easements) to human development and row crop agriculture (Copeland et al., 2014; Van Pelt et al., 2015). But as highlighted in this special issue, reducing conifer expansion is one of the few practices available to restore otherwise suitable habitats required for uplift in populations.

In this paper, we summarize key findings from a special issue of the journal *Rangeland Ecology & Management* examining socioecological aspects of woodland expansion and management actions to address this threat in sagebrush and prairie ecosystems. We highlight species and ecosystem outcomes that may result from recent efforts driven primarily by two at-risk species of high conservation concern: sage-grouse and prairie-chickens (Fig. 1). This body of literature adds to our evolving understanding of woodland expansion and treatment effects and illustrates the utility of sage-grouse and prairie-chickens as flagship species for operationalizing ecosystem restoration at consequential scales.

Background

Highly disturbed sagebrush and prairie systems are difficult to restore and unlikely to return to presettlement condition as rate and scale of modification exceed available human and financial resources (Miller et al., 2011; Arkle et al., 2014; Fuhlendorf et al., 2017–this issue). Relatively intact sagebrush and prairie ecosystems supporting sage-grouse and prairie-chickens still occupy large geographies (Fig. 2). However, sustained investment and conservation triage are needed to ensure enough of the right management actions are implemented in the right places to maximize desired ecological returns (Bottrill et al., 2008; Pyke 2011). Examples are needed of successful

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Figure 1. Greater Sage-Grouse (left; photo by: Rick McEwan) and Lesser Prairie-Chicken (right) serve as flagship species for ecosystem conservation.

application of such a strategy at ecologically meaningful scales, along with rigorous evaluations of their management efficacy. Wide-scale restoration efforts to reduce the threat of woodland expansion across prairie and sagebrush systems provide one such case study.

Expansion of woodlands in sagebrush shrublands and prairie grasslands is one threat with well-documented impacts on vegetation, water, nutrient and energy cycles, and carbon storage. Primary woodland species exhibiting expansion include Utah and western junipers (*Juniperus osteosperma* and *J. occidentalis*) and single-leaf and two-needle pinyon pines (*Pinus monophylla* and *P. edulis*) in sagebrush ecosystems and eastern red cedar (*Juniperus virginiana*) and mesquite (*Prosopis* spp.) species in prairie ecosystems (Fig. 3). Although the morphology of mesquite can often be characterized as a shrub, we refer to it here as "woodland" for simplicity and consistency. Increasing dominance of trees results in the decline of perennial grasses (Tausch and West 1995; Drewa et al., 2001; Schaefer et al., 2003; Roundy et al., 2014a), perennial forbs (Bates 2005; Dhaemers 2006), and overall herbaceous productivity and species richness (Miller et al., 2000; Briggs et al., 2002). Increasing woodland cover can reduce soil water availability, which in turn shortens the growing season (Bates et al., 2000; Fredrickson et al., 2006; Roundy et al., 2014b) and limits prevalence of forbs and grasses used by grouse for food and cover. Conversion to woodland also has

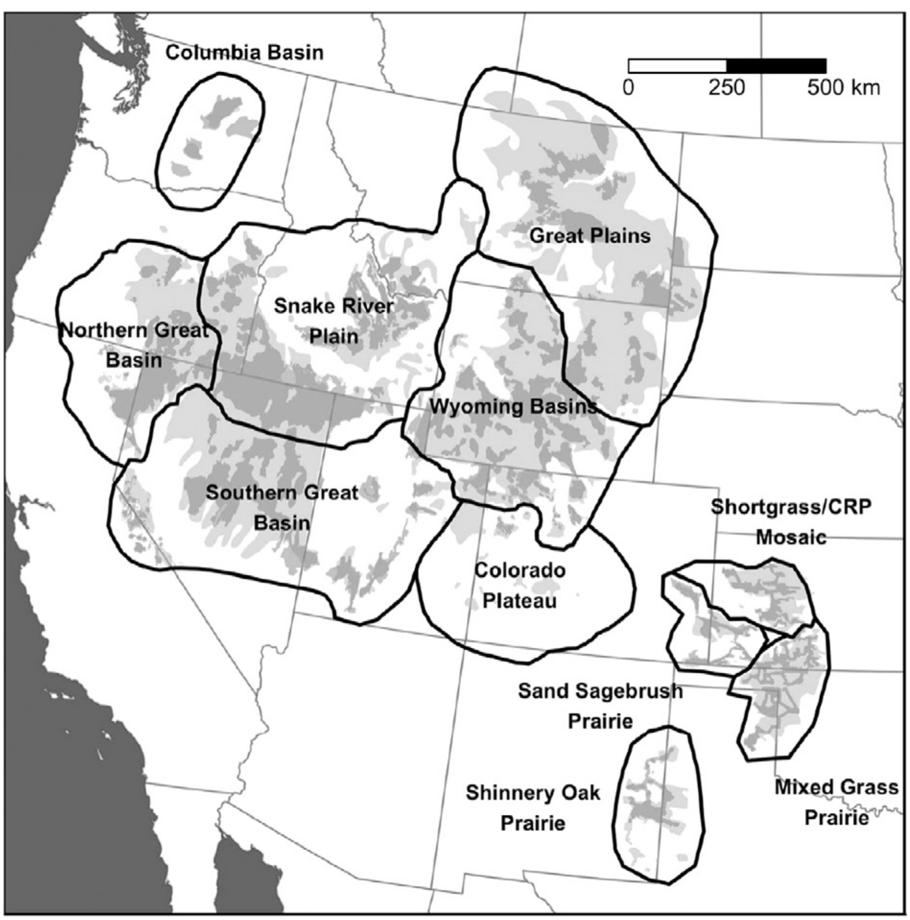

Figure 2. Upper left: Greater Sage-Grouse—occupied range (light gray; as adapted from Schroeder et al. 2004) and priority areas for conservation (PACs in dark gray; USFWS 2013) in 11 western US states and southern Canada. Sage-Grouse Management Zones are labeled by ecoregion. Lower right: Lesser Prairie-Chicken occupied range (light gray) and focal areas and connectivity zones (FACZs). PACs and FACZs depict areas supporting most of the remaining populations of sage-grouse and prairie-chickens, respectively, and represent priority areas needed for long-term persistence of the species. These priority areas facilitate implementation of conservation triage within relatively large terrestrial ecosystems.

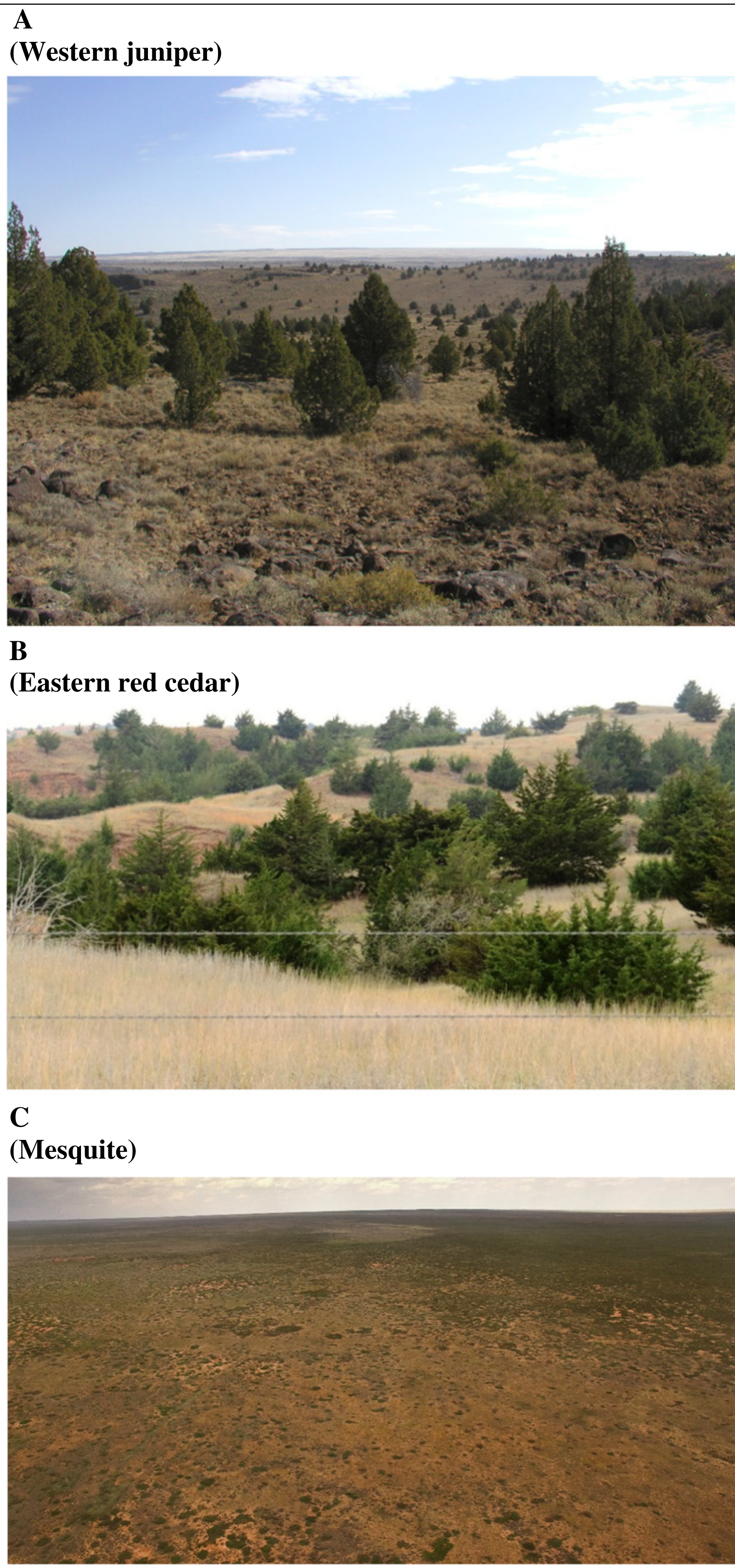

Figure 3. Woodland expansion in sagebrush steppe (**A;** photo by Todd Forbes), red cedar expansion (**B,** photo by Sandra Murphy), and honey mesquite expansion (**C,** photo by Jeremy Roberts) in prairies of western North America.

been shown to influence infiltration, runoff, erosion and sediment loads (Pierson et al., 2007, 2010; Petersen and Stringham 2009; Miller et al., 2013), resulting in a reduction of soil water availability and topsoil loss. Susceptibility to erosion following tree expansion varies with ecological site potential, as determined by climate, geomorphology, soil erodibility, and ground cover (Davenport et al., 1998). The carbon cycle changes with woodland expansion into sagebrush-steppe and prairie ecosystems because perennial grasses are a key component of the global carbon cycle and sequester large amounts of soil C (Schimel et al., 1994; Briggs et al., 2005) that decline with woodland succession. Conversion to pinyon and juniper also moves a larger portion of the carbon pool aboveground, where it is susceptible to volatilization by high intensity fires (Briggs et al., 2005; Rau et al., 2009, 2011).

Synergistically these alterations reduce the capacity of prairie and sagebrush ecosystems to be resilient to disturbances and resist invasive species pressure without undergoing shifts to novel ecosystem states (Chambers et al., 2007, 2014; Engle et al., 2008; Miller et al., 2013). Resilience is defined here as the capacity of ecosystems to reorganize and regain their fundamental structure, processes, and functioning (i.e., to recover) when altered by stressors like drought and disturbances including inappropriate livestock grazing and altered fire regimes (see Chambers et al., 2016). Reductions in perennial herbaceous plants and increases in woody fuel loads heighten the risk of high-severity crown fires in sagebrush systems and potential for conversion to an alternative state dominated by invasive annual grasses (i.e., cheatgrass [*Bromus tectorum*] and medusahead rye [*Taeniatherum caput-medusae*]) (Chambers et al., 2014; Miller et al., 2014). Excessive soil loss can also result in conversion to an eroded state that is largely irreversible (Chambers et al., 2014). Increased woody plant propagule availability interacting with altered grazing and fire regimes undermines the capacity of prairie ecosystems to return to a grassland-dominated state (Briggs et al., 2005). These state shifts also reduce ecosystem function at landscape scales by fragmenting intact sagebrush-steppe and grasslands, impairing dispersal and reproductive processes necessary to sustain plant and animal species.

Causes leading to the recent (past 150 yr) conversion of grasslands, savannas, and shrub-steppe to woodlands across the Intermountain West and Great Plains have been widely debated. Impacts are most frequently attributed to climate, livestock grazing, altered fire regimes, and changes in atmospheric carbon dioxide (Drewa et al., 2001; Briggs et al., 2005; Miller et al., 2011; Fuhlendorf et al., 2017–this issue). There is considerable evidence that climate has influenced the expansion and contraction of woodlands for millennia (Miller et al., 2011). However, the effects of climate on woodland dynamics and distribution since Eurasian settlement cannot be separated from anthropogenic factors such as altered fire regimes and grazing (Briggs et al., 2005; Miller et al., 2011). Regardless, strategic removal of expanding woodlands may be necessary to bolster the movement ability of extant populations of at-risk species to adapt to changing climate.

Population declines in two landscape species (i.e., requiring 100's to 1 000's km^2 to fulfill life-history needs), the sage-grouse and prairie-chicken, are symptomatic of woodland expansion impacts on their obligatory ecosystems (see Fig. 3). Sage-grouse and prairie-chicken habitat suitability and distribution decline with the increasing presence of trees (Fuhlendorf et al., 2002; Doherty et al., 2010; Knick et al., 2013), and conservationists have long suspected that removal of encroaching woodlands would benefit the species (Commons et al., 1999; Freese 2009; Doherty et al., 2010). Yet a nuanced understanding of population-level impacts of this top-down threat is just beginning to be revealed. Baruch-Mordo et al., (2013) were the first to confirm the reduced capacity of a landscape to support sage-grouse with increasing conifer canopy. They reported no leks remained active with > 4% conifer cover in the surrounding breeding area. Demographic consequences of woodland expansion on prairie-chickens have been documented at the landscape scale (Fuhlendorf et al., 2002). However, empirical evidence as to the impacts on space use and individual fitness has yet to be quantified. Field studies of a related species, Greater Prairie-Chicken *(Tympanuchus cupido)*, have demonstrated both broad- and fine-scale impacts of woodland expansion (Hovick et al., 2015; McNew et al., 2012). However, no replicated studies exist to quantify impacts of woodland expansion and effectiveness of tree removal to sage-grouse or prairie-chickens.

The threat of listing sage-grouse and the lesser prairie-chicken, as threatened or endangered under the federal Endangered Species Act (ESA) has led to the commitment of large financial and human resources dedicated to habitat restoration. In 2010, the Natural Resources Conservation Service (NRCS) launched the Sage Grouse Initiative (SGI) and Lesser Prairie-Chicken Initiative (LPCI) under the Working Lands for Wildlife partnership (NRCS 2015, 2016) to accelerate voluntary and incentive-based species recovery and ecosystem conservation. Investments in on-the-ground conservation through those initiatives are anticipated to exceed $671 million, making them primary catalysts for grouse and rangeland conservation in the western and south-central United States (NRCS, 2015). Along the California/Nevada border, federal, state, and private partners rallied to fully fund a $45 million action plan to conserve the distinct "bi-state" population of sage-grouse (Bi-state Technical Advisory Committee 2012). Rangewide concerns over sage-grouse also spurred far-reaching policy changes within the US Department of Interior and Agriculture affecting public land management on > 271 139 km^2 and prompting fundamental changes in wildfire prevention, suppression, and rehabilitation policies to protect sagebrush ecosystems (BLM 2015a, 2015b). Innovative approaches to conservation have emerged as well, including a habitat mitigation program administered by the Western Association of Fish and Wildlife Agencies where private investors partner with ranchers to permanently protect, manage, and fund prairie-chicken habitat improvements (Van Pelt et al., 2015). Unprecedented conservation for both species has obviated the need for federal protections under the ESA (USFWS 2015a, 2016), and conservation continues on private and public lands. Ongoing monitoring and outcome-based evaluations (Severson et al., 2017–this issue) are needed to ensure the conservation benefits are realized for these species.

A wide variety of strategies have been implemented to conserve these species, but one major emphasis of proactive restoration is a highly targeted effort to reduce conifer and mesquite expansion in and around grouse population strongholds (see Fig. 2; USFWS 2013, 2015a, b). It is part of a balanced landscape management approach that considers multiple management strategies. Private landowners through SGI and LPCI alone have addressed > 250 000 ha of woodland invasion, accelerating the pace and extent of removal > 1 400% in some instances (NRCS, 2015). States, other federal agencies, and private organizations are also deeply involved in woodland management; for example, the state of Utah with its Watershed Restoration Initiative resources has treated 120 230 ha of habitat through targeted woodland management within its Sage Grouse Management Areas (personal communication, Alan Clark, Utah Watershed Initiative). Despite the scale of conifer and mesquite treatment, scientific evaluations related to the direct effects on grouse populations have been lacking due to the relatively short amount of time since implementation. Previous studies on ecological effects of woodland removal provide important insights into potential outcomes for desired ecosystem services, especially when conducted for fuel-reduction purposes (McIver et al., 2014), but much more remains to be learned about efficacy of treatments conducted under the banner of grouse conservation.

Highlights of Special Issue

Woodland Expansion Threat

The first two papers of this special issue provide a mental model for readers to think about the importance of managing large-scale persistent threats and give practitioners the spatial data necesary to visualize their role in strategic reduction of advancing trees. Fuhlendorf et al. (2017–this issue) urge practitioners to worry less about site-specific management of remaining habitats and instead focus on reducing top-down threats such as increased dominance of trees that drive grouse populations lower by further fragmenting the landscape. Authors close with a plea to abandon the survivorship bias (Gazley and Guo 2015) wherein decision makers micromanage persistent populations while inadvertently ignoring underlying landscape-level constraints that extirpate others. In the next paper, Falkowski et al. (2017–this issue) provide managers with a large-scale view of tree canopy cover across a 11-state region (508 265 km^2). Their 1-m scale canopy cover maps for conifer and mesquite provide the first and most geographically complete, high-resolution assessment of tall woody plant cover in sagebrush-steppe and prairie ecosystems. Spatial data provide managers the ability to visualize canopy cover, estimate the extent of threat in their jurisdiction, evaluate fragmentation, quantify threat reduction following management, and assist in broad-scale outcome assessments (Falkowski et al., 2017–this issue). This study corroborates previous estimates in the Great Basin (Miller et al., 2008), finding only about 20% of the mapped sage-grouse range to be affected by dense woodland conditions (> 20% tree canopy cover), highlighting the window of opportunity that still exists on many sites in early phases of woodland succession to prevent further declines in sagebrush steppe vegetation through targeted treatment. Results also illustrate that alleviating the threat (i.e., only 10% of mapped area in woodland) for prairie-chickens may be readily achievable in the near future with a modest investment in carefully targeted early phase woodland removal.

Vegetation Response

Considerably more has been learned recently about understory vegetation response to woodland removal with a current emphasis on forbs (Chambers et al., 2013; Miller et al., 2013, 2014; Roundy et al., 2014a, b; Bybee et al., 2016). In this special issue, Bates et al. (2017–this issue) characterize the cover response of perennial and annual forbs to mechanical, prescribed fire, and low-disturbance fuel-reduction treatments. The cover response of perennial forbs, whether increasing (1.5- to 6-fold) or exhibiting no change, was similar regardless of treatment (Bates et al., 2017–this issue). This study confirmed the importance of ecological site potential (e.g., soil type, annual precipitation) as a major determinant for increasing perennial forbs following conifer control (Miller et al., 2013). Annual forbs responded most to prescribed fire with smaller increases following mechanical and fuel-reduction treatments. Treatments enhanced ecosystem resilience as evidenced by the increase in perennial herbaceous vegetation cover and reduction in bare ground, especially in Phase I (i.e., shrubs and herbaceous plants are dominant, trees subdominant) and II woodlands (i.e., shrubs and herbaceous plants co-dominant with trees) that maintain forbs on the landscape. Authors aptly describe a balancing act between managing for maximal forb response and maintaining shrubs at ecosystem scales (Bates et al., 2017–this issue).

Ecosystem Water Availability

Kormos et al. (2017–this issue) analyzed field measurements and modeling data gathered over 6 yr in southwest Idaho to explore differences in snow distribution, water availability, and annual water balances between juniper-dominated and sagebrush-dominated catchments. They found that juniper-dominated landscapes had greater peak accumulations of snow water equivalent, earlier snow melt, and less streamflow relative to sagebrush-dominated landscapes. Both juniper- and sagebrush-dominated catchments resulted in increased snow accumulation, but widespread vegetation sheltering in juniper landscapes created a more homogenous distribution of snow compared with increased snow storage in drifts induced by higher wind speeds in sagebrush landscapes. Storage of snow in drifts was more efficient at translating precipitation into higher streamflow as melting drifts slowed water release. Water delivery was delayed by an average of 9 d in sagebrush systems compared with juniper-dominated systems. The authors suggest that the retention of high-elevation, sagebrush vegetation in snow-dominated uplands may become increasingly crucial for sustaining sage-grouse brood resources, especially under warming climate conditions. In addition to extending soil water availability in the spring (Bates et al., 2000; Roundy et al., 2014a, b), this study implies conifer removal that retains sagebrush may also provide the added ecosystem service of improved water capture, storage, and delayed release in semiarid ecosystems.

Human Dimensions and Restoration Paradigms

Conservationists are championing cooperative conservation, but few examples demonstrate circumstances that create successful collaborations. Duvall et al. (2017–this issue) interviewed participating partners to explore this approach to sage-grouse conservation in the bistate region along the California/Nevada border. Findings reveal that all conservation is local and that trusted partners can transform highly contested ESA decisions into opportunities for ecosystem conservation. The bistate partnership marked a shift from single-species management to an ecosystem approach. Scientific planning and outcome-based evaluations proved certainty of effectiveness and implementation—criteria used by USFWS to evaluate conservation efforts when making listing decisions—and in 2015 precluded the need for an ESA listing (USFWS 2015).

Next, Boyd et al. (2017–this issue) challenge readers to expand their paradigm on conifer removal to include large-scale fire as a treatment—a new paradigm for most because fire is controversial in today's sage-grouse conservation. Concern regarding prescribed fire as a restoration tool stems from long-term recovery of sagebrush post fire combined with the threat of incursions of exotic annual grasses that can reduce habitat quality for sage-grouse. Accordingly, ecosystem resilience and resistance are primary considerations when selecting vegetation management strategies (Miller et al., 2013, 2014). Boyd et al. (2017–this issue) further suggest we incorporate fire into conifer management because it has twice the treatment life (up to 100 yr) of cutting. Cutting has lower up-front conservation costs because sagebrush is unaffected but is more expensive over longer management time horizons because of decreased durability and more frequent treatment requirements. The time needed for recovery of sagebrush and the prevalence of exotic invasive annual grasses creates limitations for fire applications in managing sage-grouse habitat. They suggest a combination of fire and cutting as most financially and ecologically sustainable in managing conifer-prone sage-grouse habitats, but managers will need to continue being cognizant of site conditions and resistance to invasive annuals (Miller et al., 2013, 2014; Chambers et al., 2016).

Grouse Response

Grouse-centric papers in this special issue advance our knowledge of the severity of impacts of expanding woodlands on these species. Coates et al. (2017–this issue) used extensive telemetry data to evaluate pinyon-juniper impacts on sage-grouse along the Nevada/California border. Their findings provide clear evidence that local sage-grouse distributions and demographic rates are negatively influenced by pinyon-juniper, especially in areas of higher primary productivity but relatively low conifer cover. Furthermore, they suggest that these productive, early-phase woodland sites may function as ecological traps that are attractive for grouse but adversely affect population vital rates. To maximize sage-grouse population benefits, they recommend reducing actual pinyon-juniper cover as low as 1.5% and prioritizing thorough treatment of early-phase woodlands (e.g., Phase I), particularly in productive areas, over thinning denser woodland stands. Additional evidence from Prochazka et al. (2017–this issue) across 12 Great Basin study areas documented faster movements and lower survival of sage-grouse, especially in juvenile birds, when navigating conifer-invaded sagebrush habitats. Their findings identify a likely behavioral mechanism in which pinyon-juniper expansion decreases habitat suitability. Implications are sage-grouse encounters with pinyon-juniper stimulates faster yet riskier movements that may make birds more vulnerable to visually acute predators. In Kansas, Lautenbach et al. (2017–this issue) found prairie-chickens avoid placing nests in grasslands with > 2% tree cover, illustrating a universal pattern (Freese 2009; Doherty et al., 2010; Baruch-Mordo et al., 2013; Severson et al., 2017–this issue) of low tolerance for woodlands by both sage-grouse and prairie-chickens. Similarly, prairie-chickens space themselves further from mesquite than expected at random and avoid areas with ≤ 15% canopy cover (Boggie et al., 2017–this issue). Demographic consequences of woody expansion on prairie-chickens still elude us, but population-level impacts may be a foregone conclusion, primarily because selection was marked enough that birds making "bad" fitness choices were too few to quantify in these studies.

Measuring efficacy of restoration treatments is a desired goal of adaptive management, and this special issue contains the first replicated studies documenting positive sage-grouse responses to mechanical removal of conifers. In a before-after control-impact study, Severson et al. (2017–this issue) show that nesting hens in southern Oregon were quick to use restored habitats made available by conifer removal. Within 3 yr of initiating treatments, 29% of the marked females were nesting within and near restored habitats; no such response was apparent in the nearby control landscape where conifers were not removed. Relative probability of nesting in newly restored sites increased by 22% annually, and females were 43% more likely to nest near treatments. In northwest Utah, most hens (86%) avoided conifer-invaded habitats and those using restored habitats were more likely to raise a successful brood (Sandford et al., 2017–this issue). Taken together, studies show that conifer removal can increase habitat availability for nesting and brooding sage-grouse with potential demographic benefits.

Sagebrush-Obligate Songbirds

Two additional papers examine whether benefits from conifer removal conducted ostensibly for sage-grouse extend to sagebrush-dependent songbirds. In southern Oregon, Holmes et al. (2017–this issue) found abundances of Brewer's sparrow *(Spizella breweri)*, green-tailed towhee *(Pipilo chlorurus)*, and vesper sparrow *(Poocetes gramineus)* more than doubled following mechanical conifer removal. Annual increases each year post tree removal suggest that Brewer's sparrow use may increase even more with time. Findings illustrate that conifer removal conducted for sage-grouse that retained shrub cover can result in immediate benefits for other sagebrush birds of high conservation concern, but treatment technique matters and similar responses may not be expected with broadcast burning (Knick et al., 2014). Results were from the same study area where Severson et al. (2017–this issue) documented positive sage-grouse response to conifer removal, which suggests potential utility of songbirds as additional indicators of restoration effectiveness.

Donnelly et al. (2017–this issue) advance these findings to regional scales by using count data from North American Breeding Bird Survey (2004–2014) and relevant habitat metrics to construct abundance maps for three sagebrush-obligate songbird species (Brewer's sparrow, sagebrush sparrow [*Artemisiospiza nevadensis*] and sage thrasher [*Oreoscoptes montanus*]) and quantify co-occurrence with sage-grouse lek distributions. Sagebrush land-cover predictors were primary determinants of songbird abundance, and new models show that abundance doubles when sagebrush covers ≥ 40% of the landscape. Previous sage-grouse research shows 90% of active leks are set in landscapes with > 40% sagebrush cover (Knick et al., 2013), and high probability of lek persistence is associated with > 50% cover (Wisdom et al., 2011), indicating long-term viability of songbird and sage-grouse breeding habitats may be closely linked through this common landscape requisite. Maps also revealed that strongholds for sagebrush songbirds and sage-grouse coincide; songbirds were 13–19% more abundant near large leks, which support half of all known sage-grouse populations. In the Great Basin, 85% of conifer removal conducted through the Sage Grouse Initiative also coincided with high abundance centers for Brewer's sparrow. Similar patterns were evident with Bureau of Land Management FIAT (Fire and Invasive Assessment Tool) priority project areas that coincide with half the high to moderate abundance sagebrush sparrow and sage thrasher populations in the region. The work provides new map products as additional decision support tools to further refine targeting of treatments and illustrates focused actions being implemented for sage-grouse largely overlap moderate to high abundance centers for less well-known sagebrush songbirds.

A Look to the Future

During the first symposium on woodland expansion, held in 1975 at Utah State University in Logan Utah, Terrel and Spillett (1975) concluded that the impact of pinyon-juniper conversion on wildlife was poorly documented. Few, if any, attendees would have imagined 41 years later that grouse would be driving woodland management. Sage-grouse and prairie-chicken represent two species of concern that exemplify ESA at its best—as a motivator for landscape conservation rather than a punishment for violation. Owing to their landscape-scale habitat requirements, conservation of these species also yields benefits for other less well known species in the same arc of peril.

Woodland expansion is a persistent, ecosystem-based problem that cannot simply be regulated away with the stroke of a pen (Boyd et al., 2014, Chambers et al., 2016); rather, these systems need to be adaptively managed, and concern over grouse and potential for federal listings has brought renewed interest to sagebrush steppe and prairie restoration in the American West. Yet grouse declines are only a symptom of a much larger underlying problem in the function, resilience, and integrity of these ecosystems. While these flagship species prompted recent actions, a broader ecosystem-based focus is emerging as the benefits of addressing top-down threats is more fully realized. Both Benson (2012) and Boyd et al. (2014) support this shift in focus from single-species management to conservation of ecosystems, particularly under projected changes in climate that with reduced precipitation could constrain resilience (Homer et al., 2015). In addition, such a shift attracts a more diverse group of stakeholders that will be more committed to the efforts increasing the potential for success (Duvall et al., 2017–this issue). State and transition models and simple conceptual models as suggested by Boyd et al. (2014) that help identify key components that determine ecosystem resilience and resistance to invasive species (Miller et al., 2014, 2015) are useful tools in the development of management strategies toward restoring these imperiled ecosystems.

As evidenced in this newest collection of papers, rallying conservation around flagship species can help sustain broader ecosystem functions and values. Benefits beyond grouse include maintenance of native grassland and sagebrush plant communities, conservation of nontarget sagebrush obligate avifauna, and improved water capture, storage, and release. Reducing top-down threats by partnering within local communities to identify shared goals and collaborative conservation plans are key ingredients to scaling up voluntary proactive restoration (Duvall et al., 2017–this issue; NRCS, 2016). Given lag times in habitat recovery and known boom-bust cycles in grouse, more work is needed to more fully understand longer-term population and habitat responses to management. Despite new findings about plants, birds, and hydrology, gaps remain and additional investigation is necessary to evaluate effects of woodland expansion and control on other nontarget taxa and ecosystem processes. Still, we are encouraged by the early indications that broader ecosystem benefits are being achieved through flagship species conservation, and new tools and insights presented in this special issue continue to refine conservation delivery.

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