Nevada Section Society for Range Management Suggested Reading: Winter 2019

Abstracts of Recent Papers on Range Management in the West

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NV-SRM Suggested Reading

Winter 2019

Rigby, C. W., K. B. Jensen, E. Creech, E. T. Thacker, B. L. Waldron and J. D. Derner. 2018. **Establishment and trends in persistence of selected perennial cool-season grasses in western United States**. Rangeland Ecology and Management. 71(6):681-690.

View on Science Direct: https://www.sciencedirect.com/science/article/pii/S1550742418302021

Abstract:

Restoring western US rangelands from a site dominated by invasive annuals, such as cheatgrass and medusahead, to a diverse, healthy, perennial plant − dominated ecosystem can be difficult with native grasses. This study describes the establishment and trends in persistence (plant/m^2) of native grass cultivars and germplasm compared with typically used crested and Siberian wheatgrasses at four locations in Idaho (one), Wyoming (one), and Utah (two) that range in mean average annual precipitation (MAP) from 290 to 415 mm. Sites were cultivated and fallowed 1 yr before planting using two glyphosate applications to control weeds. We monitored seedling establishment of 10 perennial cool-season grass species and plant persistence over 5 yr. Precipitation during the seeding year varied with the Utah sites locations reviving below MAP (4% and 14%), while the Wyoming and Idaho sites received above MAP at 8% and 26%, respectively. Across these four sites, native grass seedling establishment of bottlebrush squirreltail (29 ± 0.08 [standard error] seedling/m^2), bluebunch (28 ± 0.05), slender (30 ± 0.05), and Snake River wheatgrasses (28 ± 0.08) was similar to "Vavilov II" Siberian wheatgrass (36 ± 3.20). By yr 5, western, Snake River, and thickspike wheatgrasses were the only native grasses to have plant densities similar to Vavilov II (37 ± 0.29) Siberian and "Hycrest II" (36 ± 0.29) crested wheatgrasses. On sites receiving between 290 and 415 mm MAP, our data suggest that native grasses are able to establish but in general lack the ability to persist except for western, Snake River, and thickspike wheatgrasses, which had plant densities similar to crested and Siberian wheatgrasses after 5 yr.

Monaco, T. A., A. Jones, M. Pendergast, E. T. Thacker and L. Greenhalgh. 2018. **Influence of land-use legacies following shrub reduction and seeding of big sagebrush sites.** Rangeland Ecology and Management. 71(6): 695-704.

View on Science Direct: https://www.sciencedirect.com/science/article/pii/S1550742418301921

Abstract:

Big sagebrush (*Artemisia tridentata* Nutt.) plant communities often require management to reduce shrub density and rehabilitate understory vegetation. We studied vegetation responses to a two-way chain harrow treatment and broadcast seeding of 12 herbaceous species at eight Wyoming big sagebrush (*A. tridentata* Nutt. subsp. *wyomingensis* Beetle & Young) sites. These sites differed in land-use history; five were cultivated for dryland wheat production during the

1950 − 1980s and then seeded with introduced forage grasses (C-S), while three had not been exposed to this land-use legacy (non C-S). Our objective was to evaluate whether the C-S legacy influences the magnitude of vegetation change following contemporary treatment. Before treatment, C-S sites had lower sagebrush cover, higher dead sagebrush cover, and higher broom snakeweed (*Gutierrezia sarothrae* [Pursh] Britton & Rusby) cover than adjacent non C-S sites. Plant community change 3 years after treatment, determined with multivariate ordination analysis of species composition, varied between site histories, and response to treatment was most strongly correlated with reductions in sagebrush cover, increases in perennial grasses, and increases in 10 other herbaceous species—including some undesirable species and four that were seeded in 2010. Five years after treatment, mature sagebrush cover remained reduced for both land-use histories, yet density of sagebrush seedlings and broom snakeweed increased in C-S sites during the second and third years after treatment. In addition, perennial forb cover increased for C-S sites, while perennial grass biomass increased for non C-S sites. Our results emphasize that broad variability in plant community responses to sagebrush reduction and seeding is possible within the same ecological site classification and that legacy effects due to the combination of past cultivation and seeding should be considered when planning restoration projects, including the consideration that seeding may not always be necessary on C-S sites.

Metier, P., L. J. Rew and M. J. Rinella. 2018. **Establishing Wyoming big sagebrush in annual brome-invaded landscapes with seeding and herbicides.** Rangeland Ecology and Management. 71(6): 705-713.

View on BioOne: https://bioone.org/journals/Rangeland-Ecology-and-Management/volume-71/issue-6/j.rama.2018.06.001/Establishing-Wyoming-Big-Sagebrush-in-Annual-Brome-Invaded-Landscapes-with/10.1016/j.rama.2018.06.001.full

Abstract:

Seeding native plants into degraded grasslands presents major challenges. Often, seeded species fail to establish and areas become/remain dominated by unwanted plants. We combined herbicides and seeding in former coal mining fields dominated by exotic winter annual grasses (downy brome [*Bromus tectorum* L.] and Japanese brome [*Bromus arvensis L.*], hereafter "annual bromes"). The main interest was restoring Wyoming big sagebrush (*Artemisia tridentata* spp. *wyomingensis* [Beetle & A. Young] S.L. Welsh, hereafter "big sage"), a very difficult species to restore to North American grasslands. We tested the nonselective herbicide glyphosate and the grass-specific herbicide quizalofop. The summer following herbicide applications and seeding, annual brome cover in controls 22% ($CI_{95\%}$ 13%, 36%) was significantly greater ($P < 0.03$) than in glyphosate 11% ($CI_{95\%}$ 5%, 25%) and quizalofop 16% ($CI_{95\%}$ 7%, 35%) treatments. At Decker mine, glyphosate increased seeded big sage density ($P < 0.04$) from 0.76 ($CI_{95\%}$ 0.27, 2.11) to 3.05 ($CI_{95\%}$ 1.42, 6.56) plants · m^{-2} the second summer after seeding. Corresponding increases for Spring Creek mine were from 0.11 ($CI_{95\%}$ 0.03, 0.43) to 0.43 ($CI_{95\%}$ 0.13, 1.40) plants · m^{-2} ($P < 0.04$). These results were consistent across two experiments initiated in different years. In addition to big sage, our study's seed mixes contained native grasses and forbs, and herbicide treatments tended to promote establishment of these plant groups. In annual brome-dominated areas of the northern Great Plains, conditions amenable to big sage seedling establishment do not appear entirely uncommon, and herbicides can increase establishment.

Rubin, R. L. and C. M. Roybal. 2018. **Plant community responses to mastication and mulching of one-seed juniper (*Juniperus monosperma*).** Rangeland Ecology and Management. 71(6): 753-756.

View on Science Direct: https://www.sciencedirect.com/science/article/pii/S1550742418301143

Abstract:

Mechanical cutting and mastication of juniper trees aims to restore grassland habitat by reducing the density of encroaching woody species. However, the associated soil disturbance may also create conduits for invasive species, a risk that must be mitigated by land managers. We characterized herbaceous communities in treated and adjacent untreated areas in a piñon-juniper (*Pinus edulis* and *Juniper monosperma*) woodland in northern Arizona 2.5 years after treatment. Untreated plots had 4 × the herbaceous cover (82%) than treated plots (21%). Within treated plots, native species cover (19%) was 10 × higher than invasive species cover (2%). Furthermore, treated plots exhibited greater plant community variability and diversity than untreated plots, driven by an increase in the diversity of native grasses and non-native forbs. No new recruits were Arizona listed noxious weeds, indicating that, at least in the short term, mastication is not producing invasive species hot spots in this piñon-juniper woodland.

Vermeire, L. T., D. L. Strong and R. C. Waterman. 2018. **Grazing history effects on rangeland biomass, cover and diversity responses to fire and grazing utilization.** Rangeland Ecology and Management. 71(6): 770-775.

View on Science Direct: https://www.sciencedirect.com/science/article/pii/S1550742418301374

Abstract:

Exclusion of large grazers from rangelands that evolved with significant grazing pressure can alter natural processes and may have legacy effects by changing magnitude or direction of community responses to subsequent disturbance. Three moderately grazed pastures were paired with 12-ha areas with 15 yr of livestock exclusion. Six treatments were assigned to each in a 2 x 3 factorial arrangement of fire (fall fire or no fire) and grazing utilization (0%, 50%, or 75% biomass removal) to determine grazing history effects on rangeland response to subsequent disturbance. Livestock exclusion increased C_3 perennial grass (1 232 vs. 980 ± 50 kg · ha^{-1}) and forbs (173 vs. 62 ± 19 kg · ha^{-1}) and reduced C_4 perennial grass (36 vs. 180 ± 25 kg · ha^{-1}) with no effect on total current-year biomass. Diversity was greater in pastures than exclosures (H' = 1.5400 vs. 1.3823 ± 0.0431). Every biomass, cover, and diversity measure, except subshrub biomass, was affected by fire, grazing utilization, or both. Contrary to expectations, grazing history only interacted with fire effects for old standing dead material and interactions with grazing utilization were limited to old dead, bare ground, richness and dominance. Fire by grazing utilization interaction was limited to bare ground. Fire reduced annual grass (64 vs. 137 ± 29 kg · ha^{-1}), forbs (84 vs. 133 ± 29 kg · ha^{-1}), and diversity (H' = 1.3260 vs. 1.5005 ± 0.0537) with no difference in total current-year biomass (1 557 vs. 1 594 ± 66 kg · ha^{-1}). Grazing to 75%

utilization reduced total current-year biomass (1 467 vs. 1 656 ± 66 kg · ha^{-1}) and dominance (0.4824 vs. 0.5584 ± 0.0279). Grazing history affected starting points for most variables, but changes caused by grazing utilization or fire were similar between pastures and exclosures, indicating management decisions can be made based on independent knowledge of grazing or fire effects.

Hamilton, B. T., B. L. Roeder and M. A. Horner. 2019. **Effects of sagebrush restoration and conifer encroachment on small mammal diversity in sagebrush ecosystem.** Rangeland Ecology and Management. 72(1): 13-22.

View on Science Direct: https://www.sciencedirect.com/science/article/pii/S1550742418302653

Abstract:

Conifer encroachment in sagebrush ecosystems reduces habitat heterogeneity, niche space, and resource availability, all of which negatively affect many wildlife populations. Sagebrush restoration is recommended as a management action to mitigate conifer encroachment and restore wildlife across millions of hectares in the Great Basin. Despite this recommendation, the effects of conifer encroachment and sagebrush restoration are unknown for most wildlife species. Small nonvolant mammal communities include keystone species, consumers and prey; facilitate energy flow and ecological function; and provide important ecological goods and services. We assessed causal relationships between conifer encroachment and sagebrush restoration (conifer removal and seeding native plants) on small mammal communities over 11 yr using a Before-After-Control–Impact design. Sagebrush habitat supported an additional small mammal species, twice the biomass, and nearly three times higher densities than conifer-encroached habitat. Sagebrush restoration increased shrub cover, decreased tree cover, and density but failed to increase native herbaceous plant density. Restoration caused a large increase in the non-native, invasive annual cheatgrass (*Bromus tectorum* L.). Counter to prediction, small mammal diversity did not increase in response to sagebrush restoration, but restoration maintained small mammal density in the face of ongoing conifer encroachment. Piñon mice *(Peromyscus truei),* woodland specialists with highest densities in conifer-encroached habitat, were negatively affected by sagebrush restoration. Increasing cheatgrass due to sagebrush restoration may not negatively impact small mammal diversity, provided cheatgrass density and cover do not progress to a monoculture and native vegetation is maintained. The consequences of conifer encroachment, a long-term, slow-acting impact, far outweigh the impacts of sagebrush restoration, a short-term, high-intensity impact, on small mammal diversity. Given the ecological importance of small mammals, maintenance of small mammal density is a desirable outcome for sagebrush restoration.

Bates, J. D. and K. W. Davies. 2019. **Characteristics of intact Wyoming big sagebrush associations in southeastern Oregon.** Rangeland Ecology and Management. 72(1): 36-46.

View on Science Direct: https://www.sciencedirect.com/science/article/pii/S1550742418301489

Abstract:

The Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis* [Beetle & A. Young] S.L. Welsh) alliance is the most extensive of the big sagebrush complex in the Intermountain West. There is a lack of information describing vegetation characteristics, diversity, and heterogeneity of the Wyoming big sagebrush alliance. We annually sampled 48 Wyoming big sagebrush plant communities over 10 yr to delineate major vegetation associations and describe their major vegetation characteristics including canopy cover, density, species richness, and yield. Six associations were identified on the basis of dominant or codominant perennial bunchgrass species, using MRPP analysis, and they included ARTRW8 (Wyoming big sagebrush)/PSSP6 (*Pseudoroegneria spicata* [Pursh] A. Löve, bluebunch wheatgrass), ARTRW8/ACTH7 (*Achnatherum thurberianum* [Piper] Barkworth, Thurber's needlegrass), ARTRW8/FEID (*Festuca idahoensis* Elmer, Idaho fescue), ARTRW8/HECO26 (*Hesperostipa comata* [Trin. & Rupr.] Barkworth, needle-and-thread), ARTRW8/PSSP6-ACTH7, and ARTRW8/PSSP6-FEID-ACTH7. On average, PSSP6 and FEID associations had the highest total herbaceous cover and annual yields and the HECO26 and ACTH7 associations had the lowest. Perennial forb cover averaged over 5% in PSSP6 and FEID associations and ranged from 0.3% to 3.5% in the other associations. Sagebrush cover was greatest in ACTH7 and PSSP6-ACTH7 and lowest in FEID and HECO26 associations. Habitat suitability criteria for sage-grouse indicated that Wyoming big sagebrush associations at the stand/site level will generally not meet breeding habitat requirements and only attain suitable habitat requirements for other life stages about 50% of the time.

Williams, J., F. B. Pierson, P. R. Kormos, O. Z. AlHamondon, S. K. Nouwakpo and M. A. Weltz. 2019. **Vegetation, hydrologic, and erosion responses of sagebrush steppe 9 yr following mechanical tree removal.** Rangeland Ecology and Management. 72(1): 47-68.

View on Science Direct: https://www.sciencedirect.com/science/article/pii/S1550742418302185

Abstract:

Land managers across the western United States are faced with selecting and applying tree-removal treatments on pinyon (*Pinus* spp.) and juniper (*Juniperus* spp.) woodland-encroached sagebrush (*Artemisia* spp.) rangelands, but current understanding of long-term vegetation and hydrological responses of sagebrush sites to tree removal is inadequate for guiding management. This study applied a suite of vegetation and soil measures (0.5 − 990 m^2), small-plot rainfall simulations (0.5 m^2), and overland flow experiments (9 m^2) to quantify the effects of mechanical tree removal (tree cutting and mastication) on vegetation, runoff, and erosion at two mid- to late-succession woodland-encroached sagebrush sites in the Great Basin, United States, 9 yr after treatment. Low amounts of hillslope-scale shrub (3 − 15%) and grass (7 − 12%) canopy cover and extensive intercanopy (area between tree canopies) bare ground (69 − 88% bare, 75% of area) in untreated areas at both sites facilitated high levels of runoff and sediment from high-intensity (102 mm • h^{-1}, 45 min) rainfall simulations in interspaces (~ 45 mm runoff, 59 − 381 g • m^{-2} sediment) between trees and shrubs and from concentrated overland flow experiments (15, 30, and 45 L • min^{-1}, 8 min each) in the intercanopy (371 − 501 L runoff, 2 342 − 3 015 g sediment). Tree cutting increased hillslope-scale density of sagebrush by 5% and perennial grass

cover by twofold at one site while tree cutting and mastication increased hillslope-scale sagebrush density by 36% and 16%, respectively, and perennial grass cover by threefold at a second more-degraded (initially more sparsely vegetated) site over nine growing seasons. Cover of cheatgrass (*Bromus tectorum* L.) was < 1% at the sites pretreatment and 1 − 7% 9 yr after treatment. Bare ground remained high across both sites 9 yr after tree removal and was reduced by treatments solely at the more degraded site. Increases in hillslope-scale vegetation following tree removal had limited impact on runoff and erosion for rainfall simulations and concentrated flow experiments at both sites due to persistent high bare ground. The one exception was reduced runoff and erosion within the cut treatments for intercanopy plots with cut-downed-trees. The cut-downed-trees provided ample litter cover and tree debris at the ground surface to reduce the amount and erosive energy of concentrated overland flow. Trends in hillslope-scale vegetation responses to tree removal in this study demonstrate the effectiveness of mechanical treatments to reestablish sagebrush steppe vegetation without increasing cheatgrass for mid- to late-succession woodland-encroached sites along the warm-dry to cool-moist soil temperature − moisture threshold in the Great Basin. Our results indicate improved hydrologic function through sagebrush steppe vegetation recruitment after mechanical tree removal on mid- to late-succession woodlands can require more than 9 yr. We anticipate intercanopy runoff and erosion rates will decrease over time at both sites as shrub and grass cover continue to increase, but follow-up tree removal will be needed to prevent pinyon and juniper recolonization. The low intercanopy runoff and erosion measured underneath isolated cut-downed-trees in this study clearly demonstrate that tree debris following mechanical treatments can effectively limit microsite-scale runoff and erosion over time where tree debris settles in good contact with the soil surface.

Cain III, J. W., R. C. Karsch, E. J. Goldstein, E. M. Rominger and W. R. Gould. 2019. **Survival and cause-specific mortality of desert bighorn sheep lambs.** Journal Wildlife Management. 83(2): 251-259.

View on Wiley: https://wildlife.onlinelibrary.wiley.com/doi/10.1002/jwmg.21597

Abstract:

Juvenile recruitment in desert bighorn sheep (*Ovis canadensis mexicana*) is highly variable, yet the mechanisms influencing neonate survival are not well understood. Because few studies have equipped desert bighorn sheep lambs with telemetry collars, definitive data on cause-specific mortality, and lamb survival estimates are lacking. Our objectives were to estimate lamb survival rates and determine cause-specific mortality for desert bighorn sheep lambs during a period of mountain lion (*Puma concolor*) and coyote (*Canis latrans*) removal in southwestern New Mexico, USA. We captured pregnant adult females each fall and fitted them with a telemetry collar and a vaginal implant transmitter to aid with neonate captures. We captured and radio-collared 12 desert bighorn sheep lambs in 2012 and 14 in 2013 within 48 hours of parturition in the Peloncillo Mountains, New Mexico. We estimated lamb survival to 6 months of age. Across both years there were 14 mortalities, 12 of which were due to predation. Mountain lions killed 5 lambs (2 in 2012 and 3 in 2013), coyotes killed 4 lambs (all in 2013), a gray fox (*Urocyon cinereoargenteus*) killed 1 lamb in 2012, and 2 lambs were killed by unknown predators in 2013. Staged-based survival estimates indicated the highest mortality rates occurred in the first week post birth; 5 of 14 lamb mortalities occurred before 7 days of age. Lamb survival to 6 months

was substantially lower in 2013 (0.20 ± 0.11 [SE]) than in 2012 (0.71 ± 0.14) with the differences in survival attributed to increased coyote predation in 2013. We did not detect differences in body mass at birth between years or differences in body mass, chest girth, or neck circumference at birth between lambs that were killed by predators and those that survived. Coyotes, mountain lions, and the gray fox killed lambs <8 weeks of age, but only mountain lions killed lambs >8 weeks old. Predator removals focused around the parturition period of desert bighorn sheep may be more likely to influence lamb survival rates than removals outside of the lambing season.

Foster, L. J., K. M. Dugger, C. A. Hagen and D. A. Bedeau. 2019. **Greater sage-grouse vital rates after wildfire.** Journal Wildlife Management. 83(1): 121-134.

View on ResearchGate: https://www.researchgate.net/publication/327841087_Greater_sage-grouse_vital_rates_after_wildfire

Abstract:

Greater sage-grouse (*Centrocercus urophasianus*) have been subject to long-term and continuing declines in population and habitat since European settlement of western North America. Increased wildfire activity constitutes a primary threat to the species in western portions of their range, with documented declines in wildfire-affected populations. Following a 187,000-ha wildfire in southeastern Oregon and northern Nevada, USA, we used global positioning system (GPS) telemetry to monitor nest initiation, nest survival, nesting habitat, and adult survival of female sage-grouse during 2013 and 2014. We used known-fate models in Program MARK to estimate daily nest survival and monthly adult survival in relation to temporal patterns, physiological characteristics of females, and habitat and land-cover characteristics. We assessed habitat characteristics using geographic information system (GIS)-derived measures of post-fire habitat condition and land cover. Nest initiation rate following the fire was comparable to that observed in unaltered habitat. We observed nesting rates of 90% and 100% during 2013 and 2014, respectively, and renesting rates of 23% and 57% during the same years. Daily nest survival was consistently low in comparison to rates observed in concurrent studies in the region, for first nests during both years, and for second nests during 2013, but survival markedly increased for second nests during 2014. Sage-grouse generally did not leave the fire perimeter to nest, with 64% and 73% of nests located in the fire boundary during 2013 and 2014, respectively. Approximately 27% of nests were located in burned habitat during 2013, and 20% of nests in 2014 were located in burned habitat. Adult survival varied by month, and although patterns of monthly survival were similar between years, monthly survival rates were significantly reduced from the beginning of the study through the end of the first post-fire growing season. Our results indicate that sage-grouse continue to use fire-affected habitat in the years immediately following wildfire and sage-grouse experienced lower nest survival and adult female survival than other populations during the same period.

Gibson, D., E. J. Blomberg, M. T. Atamian, S. P. Espinosa and J. S. Sedinger. 2018. **Effects of power lines on habitat use and demography of greater sage-grouse (*Centrocercus urophasianus*).** Wildlife Monographs. 200(1): 1-41.

View on Wiley: https://wildlife.onlinelibrary.wiley.com/doi/full/10.1002/wmon.1034

Abstract:

Energy development and its associated infrastructure, including power lines, may influence wildlife population dynamics through effects on survival, reproduction, and movements of individuals. These infrastructure impacts may be direct or indirect, the former occurring when development acts directly as an agent of mortality (e.g., collision) and the latter when impacts occur as a by-product of other processes that are altered by infrastructure presence. Functional or numerical responses by predators to power-line corridors are indirect impacts that may suppress demographic rates for certain species, and perceived predation risk may affect animal behaviors such as habitat selection. Greater sage-grouse (*Centrocercus urophasianus*) are a species of conservation concern across western North America that may be affected by power lines. Previous studies, however, have not provided evidence for causal mechanisms influencing demographic rates. Our primary objective was to assess the influence of power lines on multiple sage-grouse vital rates, greater sage-grouse habitat selection, and ultimately greater sage-grouse population dynamics. We used demographic and behavioral data for greater sage-grouse collected from 2003 to 2012 in central Nevada, USA, accounting for sources of underlying environmental heterogeneity. We also concurrently monitored populations of common ravens (*Corvus corax*), a primary predator of sage-grouse nests and young. We focused primarily on a single 345 kV transmission line that was constructed at the beginning of our study; however, we also determined if similar patterns were associated with other nearby, preexisting power lines. We found that numerous behaviors (e.g., nest-site selection, brood-site selection) and demographic rates (e.g., nest survival, recruitment, and population growth) were affected by power lines, and that these negative effects were predominantly explained by temporal variation in the relative abundance of common ravens. Specifically, in years of high common raven abundance, avoidance of the transmission line was extended farther from the line, re-nesting propensity was reduced, and nest survival was lower near the transmission line relative to areas more distant from the transmission line. Additionally, we found that before and immediately after construction of the transmission line, habitats near the footprint of the transmission line were generally more productive (e.g., greater reproductive success and population growth) than areas farther from the transmission line. However, multiple demographic rates (i.e., pre-fledging chick survival, annual male survival, *per capita* recruitment, and population growth) for groups of individuals that used habitats near the transmission line declined to a greater extent than for individuals using habitats more distant in the years following construction of the transmission line. These decreases were correlated with an increase in common raven abundance. The geographical extent to which power lines negatively influence greater sage-grouse demographic processes was thus contingent on local raven abundance and behavior. In this system, we found that effects of power lines, depending on the behavior or demographic rate, extended 2.5–12.5 km, which exceeds current recommendations for the placement of structures in areas around sage-grouse leks. Nests located 12.5 km from the transmission line had 0.06 to 0.14 higher probabilities of hatching in years of average to high levels of raven abundance, relative to nests located within 1 km of the transmission line. Similarly, leks located 5 km from the transmission

line had 0.02 to 0.16 higher rates of population growth (λ) in years of average to high levels of raven abundance, relative to leks located within 1 km of the transmission line. Our finding that negative impacts of the transmission line were associated with common raven abundance suggest that management actions that decouple this association between common raven abundance and power lines may reduce the negative indirect impacts of power lines on greater sage-grouse population dynamics. However, because the removal of common ravens or the use of perch deterrents on power lines has not been demonstrated to be consistently effective in reducing common raven predation rates on greater sage-grouse nests, we recommend preferential treatment to mitigation strategies that reduce the number of elevated structures placed within 10 km of critical greater sage-grouse habitat.