Section 2: Leveraging Science to Address Threats to Sage-Grouse

Wesley Batterson and William Morse published *Oregon Sage Grouse* in 1948, the first publication to report the use of lek counts to monitor sage-grouse breeding populations. Over three-quarters of a century later, Oregon continues to prioritize science to guide sage-grouse management in the state by investing in needed research and adapting management accordingly.

Management decisions do not take place outside the constraints of social and administrative considerations. The interdisciplinary science of human dimensions informs decision making by considering the complex interactions between humans and their environment. Effective conservation proactively identifies where ecology need, social acceptance, and favorable administrative conditions come together (Wollstein et al. 2024).

The potential of a federal ESA listing accelerated research investments across the range, greatly improving understanding of sage-grouse biology and the ecology of sagebrush systems. New population modeling, remote sensing, and monitoring tools emerged, and technical transfer experts developed techniques to improve adoption by managers (Olsen et al. 2024).

While it would be a monumental task to summarize all the of the new findings, we will highlight some important research and tools that will be used to support and inform Oregon's approach to sage-grouse management. We rely on the frequently updated USGS annotated bibliography to remain current with the latest relevant research (Teige et al. 2023).

The scope of pervasive and perceived threats to sage-grouse and their habitats is vast and documented throughout the sage-grouse literature. The primary threats are inter-related and rooted in degraded ecological integrity. We will highlight current understanding specific to sage-grouse threats and discuss a framework for prioritization of actions to address the multitude of issues given limited resources.

The Big 3: Wildfire, Invasive Annual Grasses, and Conifer Encroachment

The "Big 3", wildfire, invasive annual grasses, and conifer encroachment, are responsible for the majority of sage-grouse habitat conversion to lower quality ecological states and resulting ecosystem dysfunction (Doherty et al. 2022). The environmental stressors that contribute to expansion of the Big 3 are complex. It is critical to understand the effects of these large-scale changes on sage-grouse demographics and behavior. ODFW and our partners have invested in important research to better understand the interaction between sage-grouse and an altered environment.

Fire

Sagebrush communities and their denizens have evolved with wildfire, but over the past 40 years, the size and frequency of wildfire has increased in Oregon and beyond (Crist 2023), contributing to a decline in sage-grouse populations (Brooks et al. 2015, Coates et al. 2016). This altered fire regime is due largely to the expansive presence of flammable invasive annual grasses, an increase in human ignitions, and hotter and drier weather in a warming climate.

Sagebrush is highly susceptible to wildfire and recovery can be slow, particularly in lower elevations with drier conditions and often poorer soils. Recovery is made more difficult by post-fire conversion of sagebrush to habitats dominated by invasive annual grasses (IAGs). IAGs are intrinsically connected to the scope and scale of wildfires in the sagebrush biome. They create continuous dry fuel beds after early summer desiccation, increasing the chance of wildfire ignition and spread. IAGs can quickly establish after disturbance, particularly in nutrient-rich post-fire habitat. This relationship between fire and IAGs creates an ever-expanding feedback loop.

Sage-grouse demographic response to fires is strongly related to the reduction in sagebrush cover that occurs after a fire. The magnitude of the effect has been well studied in Oregon. Following the 2012 Holloway Fire that burned 245,000 acres through important core sage-grouse habitat in the Trout Creek Mountains, researchers began a long-term study to examine the population response. These studies found strong negative effects of fire on critical sage-grouse vital rates. Nest success, chick and female survival were consistently lower than comparative published values (Foster 2016, Anthony 2020). Also concerning, some female sage-grouse exhibited high seasonal site fidelity to burned habitats, indicating a potential maladaptation to a landscape with more frequent disturbances (Foster 2016). Still, females were selecting nest microsites that did provide some thermal refugia from the reduced cover with some marginal effect on nest survival (Anthony 2020). Similar impacts to vital rates were confirmed in a before-after comparison of sage-grouse exposed to 2 large fire events near the Nevada/California border where adult survival was reduced by 50% and nest survival by 79% immediately post-fire (Tyrell et al. 2023).

Prevention, early detection, and rapid suppression of fire reduces the costs of fighting fire and post-fire restoration. Oregon's robust Rangeland Fire Protection Associations (RFPAs) play a vital role in providing rapid fire response in remote, fire-prone areas across the range of sage-grouse. These volunteer associations coordinate with Incident Management Teams in cooperation with the Oregon Department of Forestry (ODF), BLM, and USFS. The extreme fire year of 2024 demonstrated the importance of RFPAs when agency resources were insufficient to address multiple initial attacks. Their actions likely prevented hundreds of thousands of additional acres from burning (Figure 2.1). ODF supports RFPAs through administrative guidance to align with standards and capacity for BLM, cost reimbursement, fire suppression training, facilitating access to federal grants and surplus firefighting equipment. Support for equipment acquisition and maintenance, in addition to capacity for coordinating with Incident Management Teams is identified as critical to the continued success of RFPAs (Rural Fire Protection Associations 2024).

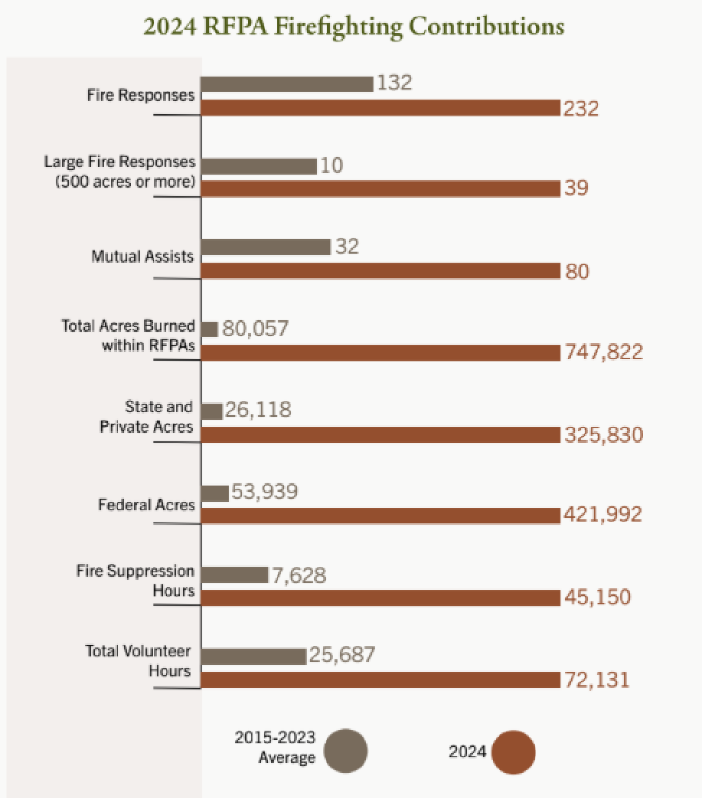

Figure 2.1. Rangeland Fire Protection Association average contributions (2015-2023) to annual fire response, compared with the extreme fire year of 2024 (Rural Fire Protection Associations 2024).

Unfortunately, fire suppression will not stop the spread of invasive annual grasses into unburned habitats (Smith et al. 2023), as the authors succinctly state, “Fire needs annual grasses more than annual grasses need fire”. Annexation of native plant communities by IAGs progresses with or without fire in sagebrush ecosystems, but fire can accelerate the transition. Suppressing wildfire is still important to protecting sagebrush ecosystems but should not be considered a solution to the IAG problem.

Invasive Annual Grasses

In Oregon, the primary species of IAGs are cheatgrass *(Bromus tectorum)*, medusahead *(Taeniatherum caput-medusae),* and ventenata *(Ventenata dubia)*. These species have high early season growth rates and seed production. The presence of these invasive grasses diminishes native plant diversity. In addition to aiding the expansion of wildfire, IAGs displace native perennial plant communities, impacting forage quality and quantity, and deteriorates cover for sagebrush-associated species.

While wildfire scope and scale are closely tied to IAG presence, other forms of disturbance also encourage IAGs, allowing incursion into previously unaffected areas such as cooler north slopes and higher elevations. Further, the disturbance of soil-biocrusts whether by hoof action or heavy equipment removes another natural suppressor of IAGs (Germino and Anthony 2022). Conifer encroachment also joins the IAG feedback loop. In the effort to remove expanding western juniper stands, the associated disturbance creates a fertile environment for establishment of IAGs.

Many techniques have been suggested as possible means to control IAGs, including biocontrol, mowing. prescribed grazing, prescribed burning, seeding, transplanting, and use various selective and non-selective herbicides (Ditomaso et al. 2017, Germino et al. 2021, Stephenson et al. 2023). The most successful method for suppressing IAGs long-term is the establishment of perennial grasses. Perennial bunchgrasses provide a barrier to IAG establishment and expansion due to their ability to outperform annual grasses in resource capture. However, perennial bunchgrasses are vulnerable to fire, and have lower seed production and fitness, particularly in environments with low resistance and resilience.

Pre- and post-emergent herbicides have shown promise in suppressing IAGs to allow establishment of perennial grasses. Two commercial products that limit the germination of seeds include imazapic (Plateau; BASF Corporation, Research Triangle Park, NC) and indaziflam (Rejuvra, Envu, Cary, NC). While there is some concern with post-emergent effects on nontarget perennials and short-lived native species, the trade-offs in highly invaded systems are acceptable, while additional caution should be used in more intact systems (Shinn and Thill 2017, Alba et al. 2024, Mumford et al. 2025). Indaziflam can remain active in the soil for more than 3 years and has shown little negative effect on established perennials. An experimental study in Colorado found that indaziflam will control cheatgrass for multiple years without impacts to perennial species richness and abundance (Clark et al. 2019). Application of imazipic in Nevada reduced cheatgrass densities by >95% in fallow plots, and grass seed mixes performed more successfully in treated vs. untreated plots (Clements et al. 2022). Native seed mixes did not outperform a combination of native and introduced perennial grass seeds in outcompeting cheatgrass. The addition of crested wheatgrass *(Agropyron cristaum)* and Siberian wheatgrass *(Agropyron fragile)* to native grass seed mixes resulted in an additional 28-32% reduction in cheatgrass density (Clements et al. 2022).

Application timing is critical as indaziflam requires 6-13 mm of precipitation after application to be activated (Rejuvra product label, Envu, Cary, NC), which can be problematic in semiarid rangelands. This treatment may be followed by a broad-spectrum herbicide, such as glyphosate, picloram, or aminocyclopyrachlor, to address current year growth and prevent additional seed production and or if there is concern for release of exotic forbs (noxious weeds), but this will also temporarily reduce native forb abundance (Clark et al. 2019). These treatments should then be followed with beneficial seed mixes and seedling planting, particularly deep-rooted bunch grasses such as bluebunch wheatgrass *(Pseudoroegneria spicata)* and shallow-rooted cool season species, such as Sandberg gluegrass *(Poa secunda)*, during the period of reduced competition from IAGs (Anthony and Germino 2023, Kluender and Germino 2023)).

Some experimental findings demonstrate the important adaptive learning framework required to find effective treatment of IAGs while minimizing the effects of native perennials. Co-application of indaziflam and imazapic had a more rapid effect on cheatgrass control than indaziflam alone in a post-fire application study in Idaho, but the results were not uniform (Kluender et al. 2025). This study also affirmed the importance of Sandberg bluegrass as an effective competitor for cheatgrass. Proactive treatment of areas with established deep-rooted perennials is more effective than re-seeding (Kleunder et al. 2025). Herbicide interception by litter is a concern for effectiveness, so post-fire applications of pre-emergent herbicides should ideally be conducted after combustion of litter (Davies et al. 2014). Follow-up treatments for patchy effects over revegetated surfaces can still contribute additional control, even if somewhat less effective (Kleunder et al. 2025). Single entry applications of imazapic and seeds are less likely to result in control of IAGs than multiple entry applications, despite perceived cost savings (Davies et al. 2014). Coating seeds with activated carbon in furrows displacing in-soil herbicide can help mitigate herbicide effects on native perennial plantings (Terry et al. 2021). Research findings continue inform best management practices for these promising herbicides.

The threat of IAGs has resulted in extensive restoration treatments that have been minimally effective. A framework of Early Detection Rapid Response (EDRR; United State Geological Survey 2024) in core habitats is important to defend high quality habitats from seemingly inevitable invasion, but appropriate site selection is critical given limited resources. A well-informed prioritization system, adaptive management and learning, incorporating local knowledge, and repeated intervention over time will improve restoration success, as well as continue investments in research with practice management applications (Germino et al. 2021).

Conifer Encroachment

Western juniper has been expanding into sagebrush systems over the past 140 years due to anthropogenic and climatic factors including fire suppression related to historic grazing practices that reduced fine fuel loads, episodic climate variation (wet periods and milder winters allowing juniper establishment ~120-140 years ago), and rising CO_2 levels (Miller et al. 2005).

The detrimental effects of the incursion of conifers, particularly western juniper *(Juniperus osteosperma)* in Oregon, into sagebrush shrublands has wide-ranging impacts from ecosystem vegetation composition, wildlife, water and nutrient cycles, carbon storage, resilience to fire, and resistance to cheatgrass. Conifer expansion is the second leading cause of decline of ecological integrity in the sagebrush biome (Doherty et al. 2022, Mozelewski et al. 2024).

Sage-grouse are particularly sensitive to tree encroachment, but respond favorably to removal (Severson et al. 2017*b* and *c*, Olsen 2019, Olsen et al. 2021, Coates et al. 2024). Female sage-grouse selected for nest and brooding sites closer to conifer removal areas and experienced improved survival and nest and brood success (Sandford et al. 2017, Severson et al. 2017*b*). A large-scale conifer removal project in Oregon found similar results with hens shifting nesting activities into areas cleared of conifer with hens 43% more likely to nest within 1000 m of treatments (Severson et al. 2017*c*). Just one year post-treatment, relative population growth rates in the treated areas began to diverge from the control, and λ was 11.2% higher by 2012 (Olsen 2019).

Conifer encroachment is also tied to lek extirpation (Baruch-Mordo et al. 2013). Sage-grouse avoidance of conifer habitats, even at low levels, is likely related to perching structure availability for avian predators. Probability of sage-grouse selecting to use a landscape declines when juniper cover reaches 1.5 - 4% (Coates et al. 2017, Severson et al. 2017a).

Mechanical tree removal, including hand felling and heavy machinery, is a common strategy to battle encroachment but can increase the risk of invasion by IAGs due to the associated surface disturbance. The presence of perennial bunchgrasses at treatment sites can reduce the likelihood of long-term annual grass dominance (Bates et al. 2005). The use of fire to remove juniper is more likely to result in sagebrush mortality, biocrust impairment, and IAG invasion (Miller et al. 2014). Sagebrush is entirely dependent on seed banks or seed immigration for recolonization after disturbance. Examinations of mechanical post-removal understory forage quality and quantity demonstrated positive effects, with measurable increases in total biomass, crude protein, herbaceous cover, perennial grass height, grass cover, and sagebrush height (Severson et al. 2017*a*, Haab et al. 2024).

While the major threats facing the sagebrush biome are daunting, not all sites are equally vulnerable. Sites with cooler soil temperature and higher moisture regimes show resistance to the spread of IAGs and resilience (recovery of perennial species) after a disturbance (Chambers et al. 2014, Chambers et al. 2017, Riginos et al. 2023). The resilience and resistance (R&R) framework has been mapped biome-wide to assist in conservation prioritization and management outcome predictions (Maestas et al. 2016). An integrated strategy including wildland fire rapid response, postfire rehabilitation, fuels management, and informed prioritization of habitat restoration is necessary to, at minimum, retain existing sage-grouse habitat.

Exacerbating Factors

Other forms of disturbance on the landscape also contribute to the ability of IAGs to infiltrate sagebrush ecosystems and replace the perennial understory. Broadly these include habitat degradation and associated stress from overgrazing by domestic livestock and free-roaming equids, anthropogenic disturbances from infrastructure, mineral and energy development, recreation, and climate change stressors. These factors are covered in significant detail in the Oregon Sage-grouse Action Plan, but we will summarize some important findings here.

Climate Change and Weather Events

While environmental conditions change throughout a species' evolutionary history, anthropogenic effects have resulted in environments changing at rates beyond which some species can adapt, particularly those with limited dispersal capabilities. For Oregon's sage-grouse, this change appears to take the form of more extreme temperature fluctuations, increased frequency of drought, and changes in dominant vegetation that ultimately increase the scale and severity of wildfire on the landscape.

An effort to predict climate change effects over the next century in southeastern Oregon evaluated four potential climate and management action scenarios (Creutzburg et al. 2015). Interestingly, all climate change scenarios projected expansion of moist shrub steppe and contraction of dry and xeric shrub steppe to varying degrees. Predicted wildfire increased by 26% over the next century under the current climate scenario, and doubled or quadrupled across more severe scenarios. Exotic grasses increased rapidly in all scenarios and the model predicted poor success in containment, but did show that control of juniper expansion in priority treatment areas was possible (Creutzburg et al. 2015).

Weather events can have a direct influence on survival of sage-grouse chicks and adults, as well as nest success (Bergerud 1988, Anothony and Willis 2009). At a longer temporal scale, shifts in climate conditions can result in changes to habitat that make portions of sage-grouse range unsuitable, resulting in decreased fitness or abandonment of the habitat.

Sage-grouse populations appear to track climate variability and are susceptible to increasing drought cycles and arid conditions expected to accompany climate change in the sagebrush biome. Sage-grouse population growth rates (λ) are positively associated with previous-year precipitation, whereas drought had a negative impact on nest survival but not adult survival (Lundblad et al. 2024). Dry weather patterns result in lower breeding rates for female sage-grouse (Behnke 2021). Wallestad and Watts (1972) found no correlation between sage-grouse productivity and rainfall or temperature in Montana, but Coates et al. (2016) found precipitation within 10 km of a lek during the previous spring, summer and fall positively influenced male sage-grouse lek attendance.

Precipitation recharges mesic areas which are critical food sources for grouse broods. Conversely, periods of prolonged drought can negatively influence populations. Nesting and brood rearing can be affected by precipitation and the associated thermoregulatory effects. In southern Oregon and northern Nevada, females hatched smaller clutches in areas that received higher amounts of winter precipitation, and rain or snow during the early brood rearing period resulted in lower chick survival rates (Street 2020).

The western US, including Oregon, experienced a 22-year megadrought from 2000 to 2021. A megadrought is a period of extreme dryness lasting for decades but including occasional years of wet conditions. Conditions in this time period were drier than any other 22-year period in the past millennium as a result of below average precipitation and above average temperatures that increase evaporation, lead to early snowmelt, and lower surface and subsurface water availability. These conditions impact water supply, streamflow, water temperature, agriculture, wildfire propensity, and overall ecosystem health.

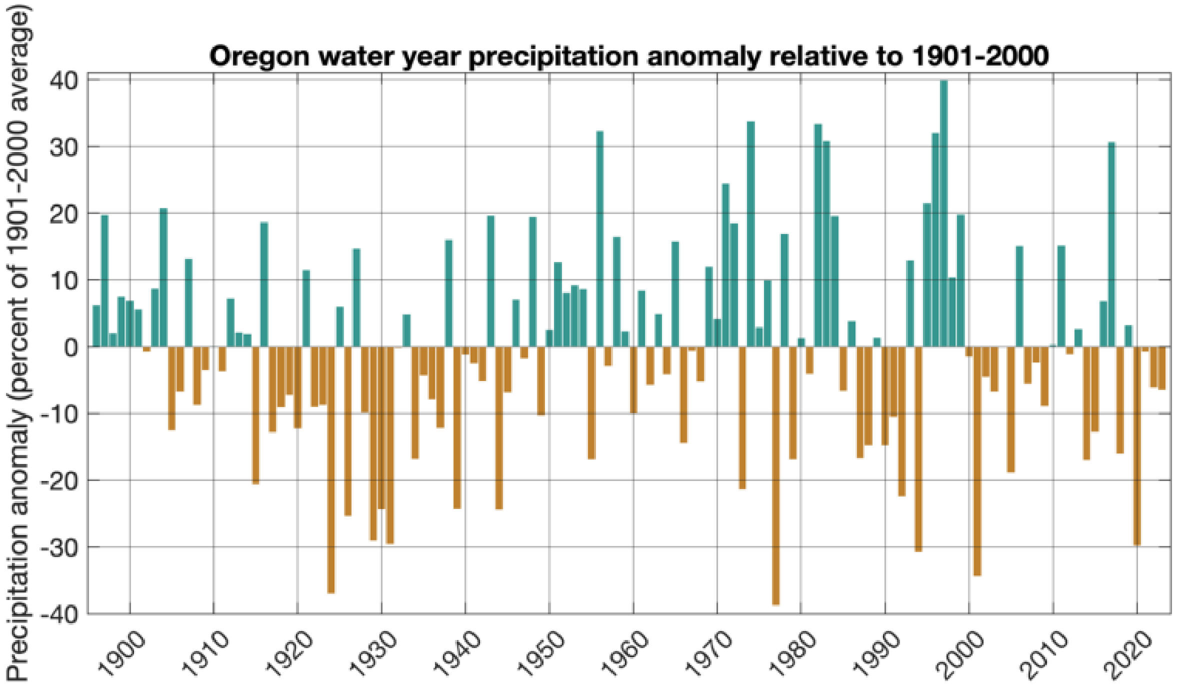

Figure 2.2. Total precipitation for the water years of 1896–2023 as a percentage of the 1901–2000 statewide average of 35.32”. Data from the PRISM Climate Group (O’Neill et al. 2023).

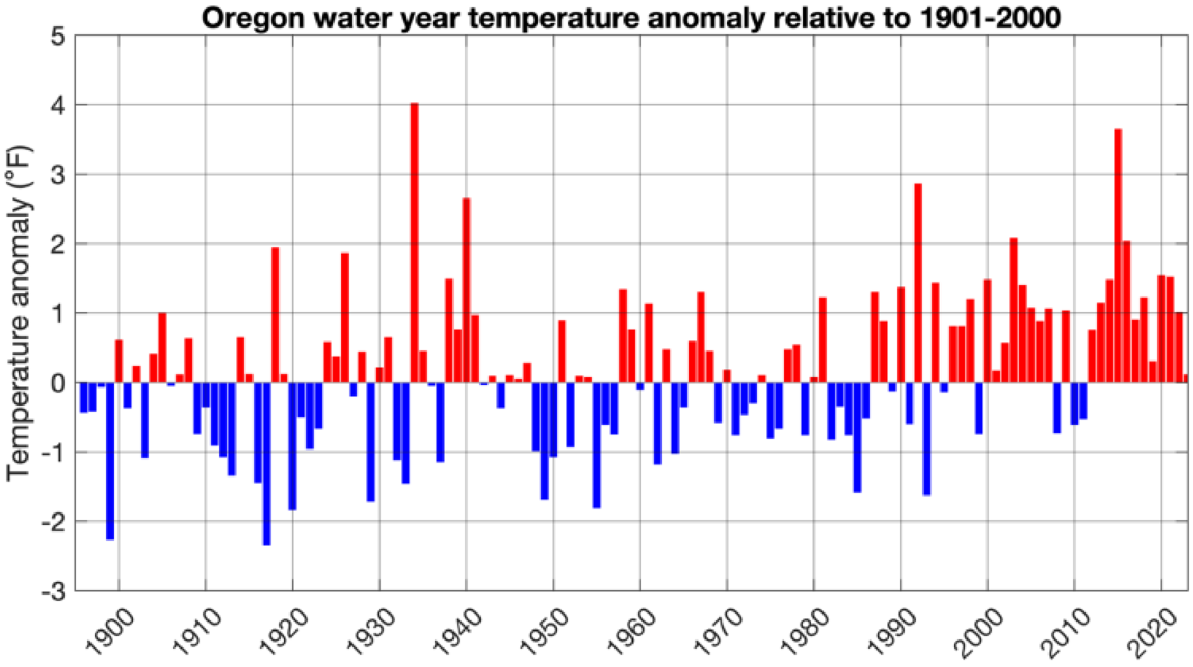

Figure 2.3. Temperature anomalies in Oregon during water years 1896–2023 relative to the average temperature from 1901–2000. Data from the PRISM Climate Group (O’Neill et al. 2023).

Patterson (1952) found no nest failure resulting from low temperatures or snow but chick survival was compromised by several consecutive days of precipitation accompanied by cold temperatures in Wyoming. The impacts of weather on brood survival depended on the availability of forbs and insects immediately following hatch in Idaho (Dalke et al. 1963, Autenrieth 1981). Sage-grouse production was reasonable when mean average temperature in spring was > 7° C (45° F) and total precipitation was <5 cm (2 in) in Colorado (Gill 1966). Adult sage-grouse endure winter reasonably well and can gain body mass during this period provided adequate wintering habitat is available (Patterson 1952). However, extreme low temperatures and accumulation of snow can influence survival in different parts of their range (Moynahan et al. 2006, Anthony and Willis 2009)

Understory Degradation and Non-native Grazers
Addressing understory degradation is one of the greatest challenges in the sagebrush biome as native vegetation communities await a solution for IAGs (Ielmini et al. 2015). Connelly et al. (2000) recommended 15-25% sagebrush cover, and at least 15% perennial grass and 10% diverse forb understory cover (≥18 cm) for breeding, nesting, and early brood rearing habitats.. Sage-grouse nest and brood success is linked to a dense herbaceous understory (Connelly et al. 1991, Gregg 1991). Sage-grouse chicks are particularly vulnerable to predation during their first 2 weeks of life. A healthy herbaceous understory provides concealment from predators, shelter from weather, and critical nutritional offerings in the pre-laying period and early brood-rearing periods. Greater forb and insect consumption has been positively correlated to chick survival (Barnett and Crawford 1994, Drut et al. 1994a, Drut et al. 1994b). Forbs and arthropods provide critical protein necessary for egg production and incubation tolerance in hens, and early growth needs for young chicks (Drut et al. 1994a, Drut et al. 1994b, Connelly et al. 2000).

The combination of unmanaged grazing, fire, and mechanical and chemical treatments have a compounding detrimental effect on forb presence, particularly when combined with the stressors of drought and a warming climate. (Pennington et al. 2016). Invasive broadleaf plants often categorized as "noxious weeds" also exclude native perennial forbs and grasses, such as various knapweeds, Canada thistle, leafy spurge, and many others, and thrive in disturbed environments. These weeds are controlled with chemical herbicides that can have long-lasting effects on non-target native forbs. Biological controls, natural enemies of specific noxious weeds, can provide long-term, host-specific control when available (Dumroese et al. 2015). When outplanting forbs back into a system with a depleted seedbank, it is important to consider the Great Basin Native Plant Project's directive, "the right seed in the right place at the right time" (Dumroese et al. 2015). Managers should use propagules and seeds collected locally, seed or plant at the right time, and consider the appropriate microsite for best success.

Livestock grazing is the predominant land use across sage-grouse range, and often implicated and litigated as a factor sage-grouse decline, particularly spring grazing on federal allotments. Early grazing practices characterized by heavy stocking rates and repeated growing season use resulted in widespread degradation of rangelands (Davies et al. 2024). Improved oversight of grazing on public land and the maturation of rangeland science aided in better stewardship of grazed rangelands, but legacy effects of perennial plant replacement with invasive plants and increased erosion, particularly near water sources, impedes habitat recovery (Williamson et al. 2020, Davies et al. 2024).

Concerns about the interaction between grazing and sage-grouse are two-fold: direct effects on sage-grouse demographics, such as nest and brood survival, and long-term impacts to habitat quality and quantity. A robust study undertaken in Idaho over 10 years involving over 1,300 radio-marked sage-grouse hen and over 1,200 nests found no evidence that low to moderate spring grazing reduced nest survival (Conway et al. 2024). Researchers also found that coexisting with bovines resulted in a greater abundance of insects in the spring, a benefit for broods. In Wyoming, sage-grouse populations responded positively to grazing after peak vegetation growth but declined with high grazing levels on cool-season grasses during peak growth (Monroe et al. 2017). In central Montana, sage-grouse hens associated with a NRCS Sage Grouse Initiative (SGI) rotational grazing system did not experience a measurable effect on nest success, and the study affirmed the importance of shrub cover and grass height to sage-grouse habitat selection (Helm 2023).

Unmanaged or poorly timed grazing can have serious impacts on understory, perennial grass cover, and palatability of forage (Forbey et al. 2013). Grazing can have the positive effect of reducing standing the standing cheatgrass crop when strategically applied (Davies et al. 2024). When comparing a gradient of grazing by both cattle and equids, Street (2020) found nest and brood sites had less cover of perennial grasses and forbs and more bare ground or cheatgrass as grazing increased. Cheatgrass cover increased with increasing horse activity at both nest and brood sites, but not with cattle grazing, likely due to heavier hoof damage and the ability to graze closer to the ground, creating more disturbance and bare ground than cattle.

In recent years, free-roaming equid (horses and burros) populations have increased in sagebrush ecosystems due to both biological and social reasons. Horses have to high growth rates, long reproductive lifespans, and a lack of natural predators. Meanwhile, wild horse advocacy groups use the legal system to delay the BLM from the process of legal removal. The BLM sets “Appropriate Management Levels” (AML) to balance grazing needs of equids, domestic livestock, and wildlife. The number of free-roaming equids has increased to approximately three times AML for all 177 Herd Management Areas administered by the BLM. Herds over AML negatively affect sage-grouse vital rates, particularly nest, brood, and juvenile survival (Beck et al. 2024). In Oregon, AML is 2,700 animals across 18 HMAs. Oregon herd numbers are estimated to increase 20% annually and were estimated around 5,000 animals as of 2025, though not all HMAs intersect sage-grouse range (BLM 2024).

Equids can alter habitat particularly in drought, disturb leks, increase bare ground, and reduce perennial grass height. Female sage-grouse initiated nests at lower rates, and expressed elevated levels of the stress hormone corticosterone, during drought years combined with the presence of abundant non-native grazers in northern Nevada and southern Oregon (Behnke 2021). When modeling sage-grouse population rate of change (λ) as a function of feral horse abundance, Coates et al. (2021) found on average, for every 50% increase in horse abundance over maximum AML, sage-grouse populations declined 2.6% annually. In Wyoming, Beck et al. 2024 documented -8% nest survival and -18% brood (early and late) and juvenile survival when max AML was exceeded by 300%.

Livestock and free-roaming equids show a strong preference for mesic habitats such as riparian meadows, particularly after cooler season forage senescence. Overuse of these habitats can create the potential for erosion, deepening streambanks, and dewatering adjacent meadows (Hockett 2002). These mesic areas are critically important for late summer brood rearing but comprise less than 2% of the landscape (Chaney et al. 1990). Belsky et al. (1999) found historic livestock grazing has altered approximately 80% of stream and riparian ecosystems in the western states. Livestock exclusion and repair of past damage provides critical benefits to late summer broods. Pioneering work by Bill Zeedyk introduced the concept of low-tech, hand-built rock structures to restore degraded wet meadows in sagebrush rangelands (Maestas et al. 2018). This idea evolved to include hand-built instream structures, such as beaver dam analogs, to raise incised channels and address headcuts, allowing rewatering of adjacent meadows (Wheaton et al. 2019).

Mining and Energy

Human population growth and associated technology has created an ever-increasing demand for energy and other raw materials. Extraction of these materials meets with concern with the volatility and long-term supply of fossil-fuels has led to a push for more renewable energy sources. The development of energy and mining infrastructure in the sagebrush biome comes at the cost of increased fragmentation from facilities, roads and transmission lines, perching structures and anthropogenic subsidies for avian predators, sound disturbance from operations, increased vehicle traffic, soil disturbance leading to spread of invasive plants, permanent removal of habitat, and impacts to surface and groundwater.

Mining and energy development are regulated by government agencies including the Department of the Interior, BLM, and Office of Surface Mining and Regulation, the Oregon Department of Geology and Mineral Industries (DOGAMI), and the Oregon Department of Energy (ODOE). Land use regulation in Oregon is administered by the Department of Land Conservation and Development (DLCD). Before a large energy facility is built in Oregon, a developer must apply for a site certificate from the Energy Facility Siting Council under ODOE.

Oregon has aggressive renewable energy goals to replace fossil fuel energy, often putting state mandates at odds with sage-grouse conservation. Oregon's "Renewable Portfolio Standard" requires large investor-owned utilities to obtain al least 27% of their energy from renewable resources by 2025, and at least 50% by 2024. Small utilities must obtain at least 5% of their electricity from renewable resources starting in 2025.

Oregon does not have the correct geology to produce large extractable supplies of oil and gas, but it does have a wealth of wind, solar, geothermal and non-fuel extractable resources including crushed stone, sand and gravel, pumice/pumicite, cement, diatomite, and perlite (U.S. Geological Survey 2025). Oregon ranks 35th in the nation for the value of nonfuel mineral production, valued at $493M in 2024. Oregon also has reserves of valuable locatable minerals including cobalt and lithium, both of which are needed to produce lithium-ion batteries.

Lithium

A Presidential determination on March 31, 2022, authorized the use of DPA Title III authorities to strengthen the U.S. industrial base for large-capacity batteries and specifically to increase domestic mining and processing of critical materials such as cobalt, graphite, lithium, and nickel for the large-capacity battery supply chain (U.S. Geological Survey 2025). On January 20, 2025, the presidential executive order entitled, “Unleashing American Energy” directed “The Secretary of the Interior, Secretary of Agriculture, Administrator of the EPA, Chairman of CEQ, and the heads of any other relevant agencies, as appropriate, shall identify all agency actions that impose undue burdens on the domestic mining and processing of non-fuel minerals and undertake steps to revise or rescind such actions.”

Along the Oregon/Nevada border, the McDermitt Caldera has been identified as a potential lithium mining site which includes some of the most intact sage-grouse habitat in the state. A proposed plan by the BLM and mineral lessees would result in drilling at more the 260 sites across 7,200 acres of sage-grouse habitat (Figure 2.X). The BLM and State of Oregon have mitigation regulations in place to address the impact of such disturbances (See Section 7).

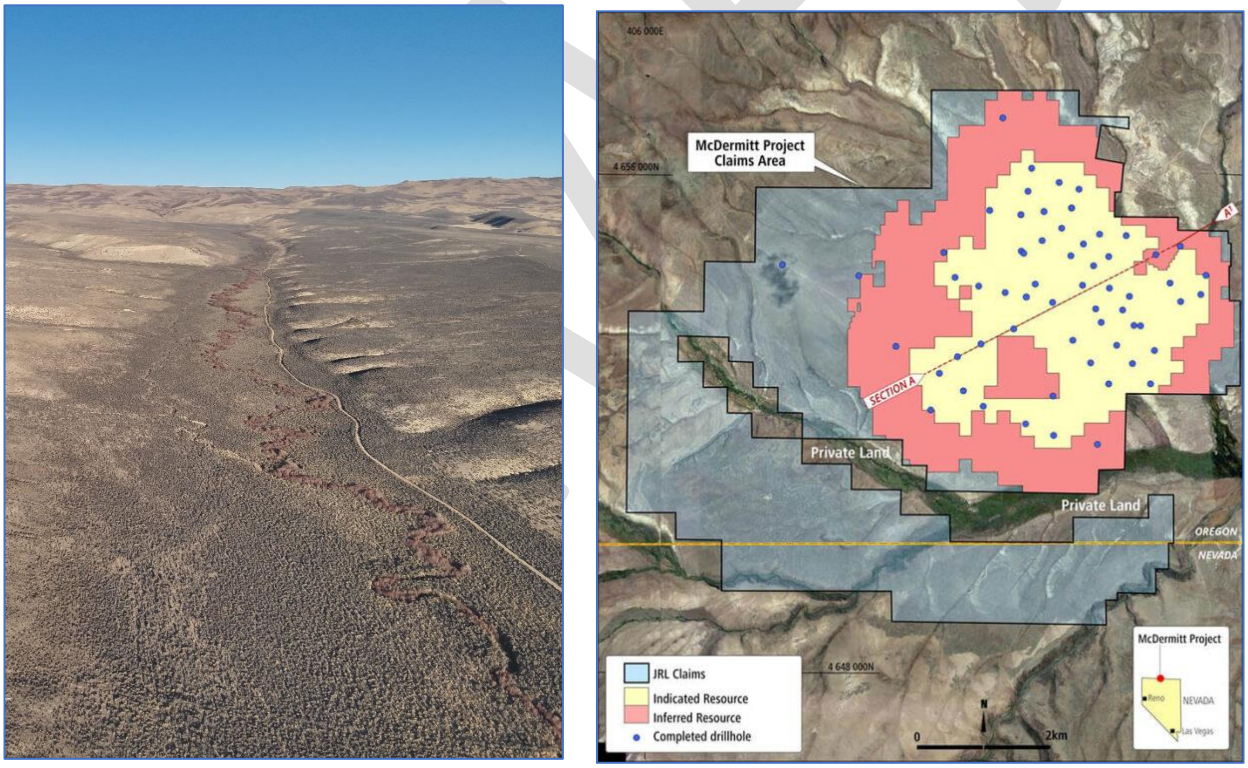

Figure 2.4. The McDermitt Caldera hosts one of the world’s largest known accumulations of lithium minerals and contains core sage-grouse habitat (photo from ODFW; map from Jindalee Resources Lithium, Perth, Australia).

Wind Energy

The construction of wind farms requires selecting and clearing sites with consistent wind resources, accompanied by road construction, buried electrical cables requiring additional surface disturbance, and associated transmission lines. Direct impacts from wind-facility development include direct mortality due to collisions with construction equipment and collisions with wind turbine blades. Raptor collisions have decreased with the tubular steel tower design and buried electrical lines, reducing perching opportunities, versus earlier designs, but bats are particularly susceptible to direct mortality. Indirect impacts specific to sage-grouse involve avoidance and decreased habitat available for use, with proximity to infrastructure in Wyoming (LaBeau et al. 2014, LaBeau et al. 2017b). Decreases in lek counts (-56%) within 1.5 km (0.9 mi) of infrastructure were documented 3 years post-installation (LaBeau et al. 2017a).

Sage-grouse feed exclusively on sagebrush during winter months, and this habitat is limited by its availability above the snowpack. Windswept ridges that keep sagebrush exposed during the winter may be prime sites for wind energy development. Because sage-grouse are dependent on sagebrush for winter forage, loss of winter habitat can have severe impacts on survival and subsequent breeding population size (Swenson et al. 1987, Connelly et al. 2004).

Geothermal Energy

Oregon has a wealth of potential geothermal energy that could be used to generate electricity with minimal carbon emissions but does not currently have active geothermal energy leases in sage-grouse core or low-density habitat. Geothermal developments would be expected to have similar impacts as other energy development facilities, including transmission lines, improved roads, fencing, and storage facilities. The noise generated can be substantial and has the potential to mask sage-grouse vocalizations during lekking, increase stress, avoidance, and lek attendance (Blickley et al. 2012a, Blickley et al. 2012b, Blickley and Patricelli 2012). In a before-after-control-impact (BACI) study in Nevada, predicted abundance declined ~24% within 5 km of geothermal sites, and lek absence rates increased by ~730% within 2 km. The study also found decreased nest survival in proximity to geothermal infrastructure, and increased density of common ravens (Coates et al. 2023). Topography also plays a role in how far sound and light carry across a landscape and cause behavioral changes in sage-grouse (Coates et al. 2023).

Solar

Photovoltaic (PV) technology converts energy radiating from the sun into electricity. In utility-scale PV facilities over 20MW, these involve a large field of solar collectors which generate electricity which is then directed to the power grid. These systems typically require 10 acres to produce 1 MW. Solar facilities are accompanied by access roads and transmission lines. There are many solar projects operating or under development within the sagebrush ecosystem, including Oregon.

From 2012-2022, annual solar generation in Oregon increased from 95,100 MWh to 2.2 million MWh, providing about 2.8% of Oregon electricity needs (Oregon Department of Energy 2024). ODFW provides recommendations on siting solar energy facilities to avoid and minimize impacts to fish and wildlife (Oregon Department of Fish and Wildlife 2024).

Impacts to sage-grouse from utility-scale PV facilities involves both fragmentation and complete removal of usable habitat resulting in displacement and reduced reproductive rates (LeBeau et al. 2017, Kirol et al. 2020). Fences and transmission lines provide perching subsidies for raptors. Maintenance roads provide travel corridors for predators, and potential food subsidies via roadkill.

Land Use and Development

Human Encroachment

Human population centers are accompanied by habitat fragmentation, agriculture, predator subsidies, roads, vehicles, transmission lines, noise, and recreation among other disturbance factors. An examination of sage-grouse persistence and extirpation considering human-caused disturbance found extirpation of sage-grouse was most likely in areas having at least 4 persons per km^2 in 1950, 25% cultivated cropland in 2002, or the presence of three or more droughts per decade. Extirpation was more likely in areas near the periphery of sage-grouse range and when sagebrush cover was less than 25% within 30km (Aldridge et al. 2008). The amount of agricultural tillage negatively affected the likelihood of large leks in northeastern Montana and southcentral Saskatchewan. Large leks were 4.5 times less likely to occur than small leks when fragmentation due to tillage exceeds 21% of land within 1.0 km of breeding sites (Tack 2009).

Telecommunication Infrastructure

Transmission lines, communication towers, and other telecommunications infrastructure, can have direct and indirect effects on sage-grouse survival. Utility wires are known to cause mortality (Borell 1939), and collisions with power lines accounted for a low percentage of mortalities in two Idaho studies (Connelly et al. 2000b, Beck et al. 2006).

Transmission line corridors provide perching subsidies for common ravens and other aerial predators. Perching on power poles and transmission structures increases a raptor or corvid's range of vision, allowing for greater speed and effectiveness in searching for and acquiring prey (Steenhof et al. 1993, Manville 2004). Increased abundance of raptors and corvids within occupied sage-grouse habitats may result in predation rates outside the range of natural variation (Lammers and Collopy 2007, Coates 2007). Proximity to power lines was related to decreased lek attendance, nest site selection, nest success, and brood success (Gibson et al. 2018, Kohl et al. 2019, Lebeau et al. 2019). In a 9 year study in central Nevada, the extent to which power lines influenced sage-grouse nest success and probability of lek growth was closely tied to common raven abundance (Gibson et al. 2018) The effects of the power lines on sage-grouse demographics extended 2.5-12.5 km (Gibson et al. 2018).

Transmission structures may provide nesting sites for corvids and raptors in habitats with low vegetation and relatively flat terrain. Thus, these birds may preferentially seek out transmission structures in areas where natural perches and nesting sites are limited. For example, within one year of construction of a 372.5 mi transmission line in southern Idaho and Oregon, raptors and common ravens *(Corvus corax)* began nesting on the support structures, and within 10 years of construction 133 pairs of raptors and ravens were nesting on the transmission structures (Steenhof et al. 1993). Ravens are particularly adaptable to new structures on the landscape. In a

Nevada study, raptor observations remained stable over a 5 year period after construction of a power line in Nevada, but common ravens increased >200% (Atamian and Sedinger 2007).

Golden eagle *(Aquila chrysaetos)* predation of sage-grouse increased from 26% to 73% (of the total predation) after a transmission line was constructed within 220 yd of an occupied lek in northeastern Utah (Ellis 1984). The lek was extirpated, and Ellis (1984) concluded that the presence of the transmission line resulted in changes in sage-grouse dispersal patterns and fragmentation of the habitat. In Washington, 95% (19 of 20) of leks ≤4.7 miles from 500 kV transmission lines are now unoccupied, while the unoccupied rate for leks >4.7 miles is 59% (22 of 37 leks; Washington Department of Fish and Wildlife 2008). Leks within 0.25 miles of new power lines constructed for coalbed methane development in the Powder River Basin of Wyoming had significantly slower growth rates compared to leks further from these lines, which was presumed to be the result of increased raptor predation (Braun et al. 2002).

The presence of a transmission lines may fragment sage-grouse habitats even if raptors and corvids are not present. Braun (1998) found that use of otherwise suitable habitat by sage-grouse near power lines increased as distance from the power line increased for up to 660 yd. The report also noted the presence of power lines may limit sage-grouse use within 0.6 miles in otherwise suitable habitat. Similar avoidance behavior has been documented in closely related species such as greater *(Tympanuchus cupido)* and lesser prairie-chickens *(Tympanuchus pallidicinctus)*, where habitats within 1 mile of power lines were avoided (Hagen et al. 2004, Pitman et al. 2005, Robel et al. 2005, Pruett et al. 2009).

Recreation

The impacts of recreational activity on sage-grouse habitat have been poorly documented in the literature. However, displaying males or visiting female sage-grouse have been known to abandon lek sites frequented by birdwatchers and photographers who observe and photograph at distances not tolerated by the birds (Call 1979). Off highway vehicle (OHV) use also may be detrimental to sage-grouse breeding or nesting activities if the timing and intensity of the activity conflicts with sage-grouse use of those areas. Intensive off-trail OHV use may cause nest abandonment, if laying or incubating females are flushed from nesting locations. Previous work on sage-grouse indicates that it is one of the most sensitive grouse species with respect to abandoning a nest once disturbed (Patterson 1952).

Direct mortality

Disease and Parasites

Christiansen and Tate (2011) list 36 diseases and internal and external parasites known to infect sage-grouse. The suppressive effect of these organisms is a particular concern for small, isolated populations where reduced fitness increases the likelihood of extirpation. While mortality events are uncommon, Batterson and Morse (1948) reported a sage-grouse population crash in Oregon in 1919-1920 when dead and dying grouse were common throughout the preferred portions of their range. Due to their sensitivity to moisture and temperature, certain pathogens may be subject to amplification due to climate warming and the increases susceptibility of the sage-grouse host due to the stressors of anthropogenic disturbance (Christiansen and Tate 2011).

In general, there has been little focus on monitoring and research of sage-grouse disease, until the emergence of West Nile Virus (Flaviviridae, *Flavivirus;* WNV). This mosquito-borne virus from Africa, was introduced to the U.S. in 1999 and has since become endemic. When WNV reached the western U.S. in 2002, sage-grouse were highly vulnerable, and populations were reduced by up to 25% in some areas. ((Naugle et al. 2004, Moynahan et al. 2006). Total mortality from WNV has been markedly reduced since 2003 but is still a source of mortality in sage-grouse. Due to the connection between the mosquito host and standing water, sage-grouse may be more vulnerable during drought conditions when birds congregate near the remaining water sources, particularly at lower, warmer elevations (Naugle et al. 2004, Walker and Naugle 2011).

Oregon began monitoring live sage-grouse captured during research projects for WNV in 2004 in cooperation with the National Wildlife Health Center (NWHC). In 2006, a die-off of at least 60 sage-grouse was documented near Burns Junction, and two other sage-grouse deaths were confirmed from WNV near Crane and Jordan Valley. Monitoring expanded from 2006-2010 when the NWHC tested more than 1,800 blood samples from hunter- harvested birds in Oregon. The tests found a low prevalence of WNV antibodies (n = 19), and only one infected sage-grouse, a juvenile male harvested in in northern Malheur County (Dusek et al. 2014). The lack of antibodies in the population is indicative of lack of resistance to the disease, however no other significant mortality events have been documented in Oregon since 2006.

Predation

Survival of sage-grouse is typically high with more than approximately 60% of a cohort surviving from year to year. Of the 40% of a sage-grouse population that succumbs to mortality during a year, predation accounts for approximately 85% of reported non-hunting mortalities and 79-94% of nest failures (Bergerud 1988, Moynahan et al. 2007). Specifically, predation on nests and young chicks can be high and affect populations (Gregg et al. 1994, Aldridge and Brigham 2001, Schroeder and Baydack 2001, Coates 2007). In Idaho, predation was the most common cause of death for radio-marked sage-grouse (83% of males and 52% of females) in a hunted population (Connelly et al. 2000a). In Nevada, predation accounted for 90% of all mortalities, and adults were less vulnerable than subadults (Blomberg et al. 2013). The suite of predators on the landscape can vary with prey availability and habitat suitability (Hagen 2011).

Predation rates may depend in part on the availability of alternative prey for predators, such as cottontail rabbits (*Silvlagus* spp.), jackrabbits (*Lepus* spp.) or other small mammals (Willis et al. 1993). Additionally, habitat quality may influence the rates of predation on sage-grouse (Schroeder and Baydack 2001). Predation is probably most frequent on adult males during or shortly after the breeding season and on females during incubation and brood rearing (Schroeder et al. 2020, Hagen 2011). In Nevada, predation risk on sage-grouse by mammals was higher than raptors in the fall, but more equivalent during the nesting season (Blomberg et al. 2013). A non-exhaustive list of observed sage-grouse predators is provided (Table X), but most studies concur that coyotes, common ravens, golden eagles, and American badger represent the vast majority of sage-grouse and sage-grouse nest predators (Conover and Roberts 2017).

Predator	Adult	Juvenile/Subadult	Nest
Mammals			
Coyote *(Canis latrans)*	X	X	X
Red Fox *(Vulpes vulpes)*	X	X	X
American Badger *(Taxidae taxus)*	X	X	X
Bobcat *(Lynx rufus)*	X		X
American mink *(Neovison vison)*	X		
Weasel *(Mustela* spp.)		X	X
Striped Skunk *(Mephitis mephitis)*			X
Ground Squirrel *(Spermophilus* spp)			X
Elk *(Cervus canadensis)*			X
Pronghorn *(Antilocapra americana)*			X
Raccoon *(Procyon Lotor)*			X
Birds			
Golden Eagles *(Aquila chrysaetos)*	X	X	
Bald Eagles *(Haliaeetus leucocephalus)*	X	X	
Prairie Falcon *(Falco mexicanus)*	X	X	
Gyrfalcon *(Falco rusticolus)*	X	X	
Northern Goshawk *(Accipiter gentilis)*	X	X	
Coopers Hawk *(Accipiter gentilis)*	X	X	
Ferruginous Hawk *(Buteo regalis)*		X	
Red-tailed Hawk *(Buteo jamaicensis)*		X	
American Kestrel *(Falco sparverius)*		X	
Merlin *(Falco columbarius)*		X	
Northern Harrier *(Circus cyaneus)*		X	
Great-horned Owl *(Bufo virginianus)*	X		
Snowy Owl *(Bubo scandiacus)*	X		
Common Raven *(Corvus corax)*		X	X
Black-billed Magpie *(Pica hudsonia)*			X
Snakes			
Western Rattlesnake *(Crotalus oreganus)*			X
Western Gopher Snake *(Pituophis catenifer)*		X	X

Table 2.2. Summary of observed predators of adult, sub-adult or juvenile sage-grouse and sage-grouse nests (Hagen 2011, Conover and Roberts 2017, Taylor et al. 2017, Schroeder et al. 2020).

Controlling predators is controversial and generally not sustainable at large spatial or temporal scales. Experimental removal of coyotes in Wyoming actually resulted in decreased sage-grouse nest success, likely due to mesopredator release, whereas raven removal can increase nest success (Dinkins et al. 2016). Counts of male sage-grouse on leks increased the years following raven removal, indicating population-level effects (Peebles et al. 2017).

Common ravens *(Corvus corax;* ravens) are a generalist predator that have increased in resource-limited arid environments due to anthropogenic subsidies providing food and nesting structures. These subsidies increase the densities and growth rate of ravens and increase the landscape carrying capacity for ravens (Dinkins et al. 2021, Revekant 2021). Ravens have also been linked to recently burned habitats, but road density appears to be one of the most important determining factors (O’Neil et al. 2018, Dinkins et al. 2021, Owens 2023). Raven numbers have increased 300% in the western U.S. since 1980 (Sauer et al. 2008) and have much higher abundance

(+203%) within the range of sage-grouse than outside (Harju et al. 2021). Raven predation is typically associated with nest raiding, and ravens have been shown to disrupt male lekking behavior (Atkinson et al. 2024). A density threshold of ravens exceeding 0.40 km^2 is shown to have negative impacts on sage-grouse nest survival (Coates et al. 2020). Raven density has been linked to sage-grouse nest failure, particularly in areas of low shrub canopy cover (Coates and Delehanty 2010). The foraging patterns of transient, resident, and resident-nesting ravens and their relative impacts on sage-grouse nests are not well understood. It is likely that ravens provisioning nests and defending a territory are more likely to forage in closer proximity to their nest, which can lead to increased likelihood of sage-grouse nest discovery by nesting ravens (Bui et al. 2010, Dinkins et al. 2016).

The USFWS authorized ODFW to initially remove raven nests and then lethally remove adult ravens in the vicinity of nesting habitat within Oregon's Baker PAC starting in 2021. The density of ravens in the Baker PAC is estimated at 0.52 ravens/km^2, exceeding the threshold determined by Coates et al. (2020). In cooperation with Oregon State University, this study includes raven habitat use and density monitoring, sage-grouse space use, sage-grouse hen demographics and movement monitoring, experimental removal of anthropogenic subsidies (e.g. roadkill), and a nutritional analysis of raven fecal samples to determine the extent to which ravens consume sage-grouse eggs in this declining PAC (Owens 2023, Perry 2023. Dinkins 2024). Reference study sites include the Bully Creek, Cow Lakes, Crowley (2017-2019) and Soldier Creek PACs. The results of this study will inform ODFW's approach to raven removal in association with severely imperiled populations of sage-grouse.

Harvest
Hunter harvest can contribute either compensatory or additive mortality to sage-grouse populations, but determining the appropriate level of harvest has been a challenge to researchers (Sedinger et al. 2010, Dinkins et al. 2021a). Because sage-grouse do not fit the 'high productivity-short life span' life history model common to other game bird species, the assumption has been questioned that harvest mortality replaces birds that would have died of other causes during the year (i.e., compensatory mortality) (Johnson and Braun 1999). However, Coates et al. 2016 found a significant density dependent effect when modeling three decades of sage-grouse lek counts in the context of chronic wildfire impacts. Connelly et al. (2000a, 2003b) suggested that hunting losses are likely in addition to winter mortality for adult females (i.e., additive mortality). Johnson and Braun (1999) modeled population dynamics for sage-grouse in North Park, Colorado, and concluded that hunting mortality can be additive to other sources of mortality, especially in years of poor recruitment.

Experimental studies have found difficulty in decoupling the confounding effects of density-dependence, harvest, and population size (Sedinger and Rotella 2005). Connelly et al. (2003b) demonstrated that rates of population growth were less in hunted than unhunted populations in Idaho, but did not account for density-dependence. A more robust model accounting for density-dependent population growth found mixed results on the relationship between sage-grouse hunting regulations history and base population growth, concluding higher harvest exposure (30-day season vs. 0 or 7 day seasons) could result in population suppression (Dinkins et al. 2021b).

Twenty years of harvest data from Oregon did not indicate a correlation between harvest level and spring breeding population (Crawford 1982). Braun and Beck (1985) analyzed banded birds, harvest levels, and lek counts and concluded that the harvest rate of 7-11% in Colorado had no measurable effect on sage- grouse densities in spring. Similarly, a band-recovery study in Colorado and Nevada sage-grouse concluded that harvest rates <11% appear to be compensatory in nature (Sedinger et al. 2010).

Recreational hunting was determined not to be a threat to sage-grouse populations in the 2010 and 2015 USFWS ESA listing decisions as state and provincial agencies adopted increasingly conservative approaches to regulated hunting. (U.S. Fish and Wildlife Service 2010a, U.S. Fish and Wildlife Service 2015). Range-wide sage-grouse management guidelines recommend a harvest rate of 10% or less (Connelly et al. 2000). Oregon's policy has been for harvest not to exceed 5% of the fall population and in practice harvest has been estimated at <3% of the fall population in the hunted areas (Vold 2023). Sage-grouse are not hunted range-wide in Oregon; regulated hunting is permitted in (all or portions of) 9 out of 21 WMUs where sage-grouse occur. Oregon's sage-grouse harvest strategy is held as an example of adaptive harvest management likely to ensure population persistence, though the strategy could benefit from an explicit feedback loop (population simulation) to link harvest to next-year populations (Dahlgren et al. 2021). At some level of harvest, sage-grouse hunting mortality is likely to become additive without an adaptive, conservative, and controlled recreational harvest management strategy.

Pesticides

Insecticides are used by USDA's Animal and Plant Health Inspection Service (APHIS), in cooperation with the Oregon Department of Agriculture (ODA), to suppress grasshopper and Mormon cricket outbreaks in eastern Oregon on federal, state, and private lands. In Oregon, only liquid diflubenzuron (Dimilin), for immature insects, or solid bait carbaryl, for mature grasshoppers, are considered for use. There is low potential that these insecticides would be toxic to sage-grouse either by direct exposure or through consuming treated insects. The primary concerns with these treatments are reduced availability of insect prey by juvenile sage-grouse. The APHIS Environmental Assessment includes additional conservation measures for application of grasshopper and Mormon cricket control to minimize impacts and disturbance to sage-grouse (U.S. Department of Agriculture - APHIS 2022).

Organophosphorus insecticides which inhibit acetylcholinesterase, an enzyme essential for central nervous system function have been found to be directly responsible for death of sage-grouse in proximity to agriculture fields in southeastern Idaho (Blus et al. 1989). Sage-grouse can be attracted to the green vegetation and insects associated with irrigated crops, particularly alfalfa, during the late summer brood rearing period (Hagen et al. 2007, Connelly et al. 2011b). The registration of organophosphorus insecticides methamidophos and disulfoton in the U.S. was voluntarily suspended in 2009 (Environmental Protection Agency 2009), but dimethoate is still widely used on agricultural crops.

Vehicle and Fence Collisions

Roads can cause direct mortalities via collisions in addition to increasing noise disturbance, fragmentation of habitat, and increased presence of avian predators, all affecting the fitness of sage-grouse populations (Manier et al. 2014). Juvenile sage-grouse are most susceptible to collisions with vehicles (Wallestad 1975, Aldridge and Boyce 2007). Mortalities from vehicle collisions were more frequent than collisions with wires and fences in Montana (Wallestad 1975). Vehicles accounted for 4%-6% of mortalities among radio-marked females in Idaho and Montana (Connelly et al. 2000a, Sika 2006). Avoidance of roads, particularly by nesting sage-grouse hens, may be related to selecting habitats with lower avian predator densities (Dinkins et al. 2014).

Barbed wire fences are ubiquitous across the western landscape, and a cause of direct mortality in sage-grouse, particularly in the vicinity of large leks. A barbed wire fence in winter habitat killed at least 36 sage-grouse the first winter after installation (Call and Maser 1985), and 21 mortalities were reported along a similar fence in Wyoming (Connelly et al. 2004). Fence marking with reflective markers hung from the top strands of fences has proven to reduce collisions. In Wyoming, 11.36 and 4.55 sage-grouse strikes/mile were detected along an unmarked and marked fence, respectively in a 1.5 year time period (T. Christiansen, WGFD, 2009 unpubl. Rep.). In Idaho, 3.5 versus 6 sage-grouse strikes/mile were documented along unmarked and marked fences, respectively, an 83% reduction in collisions (Stevens et al. 2012). Long-term monitoring of fences in southwestern Wyoming detected over 1,000 collisions of which 60% occurred on marked fences, and observed increased collisions near locations where sage-grouse congregate regardless of the time of year (Woolwine et al. 2024).

A Framework for Addressing Threats

The Sagebrush Conservation Design and Threat-Based Strategic Conservation

The Sagebrush Conservation Design (SCD; Doherty et al. 2022), was developed by a working group of diverse experts to support and inform WAFWA's Sagebrush Conservation Strategy Part 2 (Western Association of Fish and Wildlife Agencies 2025). The SCD leverages remotely sensed landcover to model sagebrush ecological integrity and divides the biome into:

1) Core Sagebrush Areas (CSAs),
2) Growth Opportunity Areas (GOAs), and
3) Other Rangeland Areas (ORAs).

The SCD provides a prioritization framework for a proactive conservation approach first articulated by the NRCS (2020): "Defend the Core, Grow the Core, Mitigate Impacts". This concept prioritizes first protecting intact, functioning sagebrush ecosystems, then expanding outward from the core, rather than first focusing on the most degraded habitat.

Importantly, the SCD documented that 87% of habitat losses in CSAs were due to increases in two threats: invasive annual grasses and conifers, whereas 4% of loss was attributed to perennial grass decline, and 3% of loss was directly causes by human modification. The SCD also showed that 1.3 million acres of intact sagebrush is lost on average each year. This analysis brings into sharp relief that Oregon must prioritize the crisis of invasive annual grass conversion and conifer encroachment into sagebrush ecosystems, and intertwined wildfire interactions, utilizing the "Defend the Core" framework. When relating the SCD sagebrush ecological integrity index to sage-grouse population trends, authors found growth rates of populations were stable to positive in core areas and negative to strongly negative outside the core areas (Doherty et al. 2022).

Applying this framework at an effective and relevant scale motivated the development of "Threat-Based Strategic Conservation" by experts from Oregon's Sage-Steppe Habitat Response (Sage-SHARE) working group. Using the concepts of the SCD and Threat-Based Land Management (Johnson et al. 2019), this exercise demonstrates how to transfer the "Defend the Core" concept to management-relevant scales utilizing Threat-based Ecostate Maps (Institute for Natural Resources 2023) and a set of five general principles (Figure 5; Sage-SHARE 2022).

Five Principles of Threat-Based Strategic Conservation

1. Prioritize defending and growing the core from primary ecosystem-level threats.
2. Find the relevant scale and people for your area.
3. Let your WHY guide your WHERE and WHAT.
4. Beware of both action bias and action paralysis.
5. Remember that conservation is empowered by relationships.

Figure 2.5. Guiding principles of threat-based strategic conservation (Sage-SHARE 2022)

Threat-based ecostate maps consist of a set of 33 maps representing 3-year averages of rangeland ecosystem condition, allowing managers to track the change in ecological state over time. The percent cover data comes from the Rangeland Analysis Platform, developed by the USDA and University of Montana using remote sensing combined with ground-truthing and machine learning technology to map vegetation (RAP; Version 3). There are 8 threat-based ecostates that describe current vegetation composition combined with a level of threat from invasive annual grasses, wildfire, and juniper encroachment severity (Table 2.1). These maps represent a critical tool in Oregon's ability to monitor sagebrush ecosystem condition.

Ecostate	Description	Shrub Cover	Herbaceous Cover	Tree Cover
A	Good Condition Shrubland	>12%	Perennials exceed annuals by 3:1	<5%
A-C	Intermediate Condition Shrubland	>12%	Perennials dominant over annuals between 1:1 and 3:1	<5%
C	Poor Condition Shrubland	>12%	Annuals dominant	<5%
B	Good Condition Grassland	<12%	Perennials exceed annuals by 3:1	<5%
B-D	Intermediate Condition Grassland	<12%	Perennials dominant over annuals between 1:1 and 3:1	<5%
D	Poor Condition Grassland	<12%	Annuals dominant	<5%

Tree	Low-mid Cover	N/A	N/A	5-20%
Tree	High Cover	N/A	N/A	≥ 21%

Table 2.1. Description of the 8 threat-based ecostates as developed by the Institute for Natural Resources (2023).

The next logical tier in this process is the creation of a statewide spatial strategy to inform and prioritize sage-grouse habitat conservation at the implementation level. This spatial decision support tool would assist cooperative efforts in determining the appropriate action to take in conservation efforts, considering both sage-grouse demographic information and habitat condition. Decision support resources are emerging to assist with this effort, particularly the USGS PReSET (Prioritizing Restoration of Sagebrush Ecosystems Tool; Aldridge et al. 2024). This decision-support tool generates maps of prioritized sites for restoration and conservation actions, based on customized management objectives such as restoring habitat connectivity or preserving sagebrush habitat resilient to drought.

An important example of the application of Threat-based Strategic Conservation is the framework proposed by Boyd et al. (2024) to address the threat of IAGs. This framework involves both proactive maintenance of intact habitat and restoration of adjacent impacted sites, before addressing the most impacted sites. This model builds on the Sagebrush Conservation Design (Doherty et al. 2022) to provide specific guidance for managers addressing the threat of IAGs. Priority maps designated management recommendations under the framework of MAINTAIN, IMPROVE, and CONTAIN (Figure 2.6). Similar approaches can be applied to other threats under this framework, such as conifer encroachment and wildfire risk.

Categories of IAG Management Priorities

MAINTAIN: Places with high ecological integrity at high risk of future invasion.
Management: Early detection and rapid response; enhance resistance, manage propagule pressure.

IMPROVE: Places that are currently impacted by invasive annual grasses, but could be restored to high ecological integrity with active intervention.
Management: Actively suppress invasive annual grasses and restore competitive, climate-appropriate perennials.

CONTAIN: Places severely impacted by invasive annual grasses, where abiotic conditions make restoration success unlikely.
Management: Manage as annuals-dominated system. Prioritize fire prevention and fuels management; prevent spread.

Figure 2.6. A framework for addressing the threat of invasive annual grasses as informed by Threat-Based Strategic Conservation and the Sagebrush Conservation Design (Boyd et al. 2024).

Summary

Wildfire, invasive annual grasses, and conifer encroachment in the context of a highly human-influenced landscape and climate, have lowered the demographic rates of sage-grouse and caused abandonment of large areas of previous sage-grouse range. Many other factors can contribute to lower adult, nest, brood, and juvenile survival, including disease, parasites, predation, harvest, pesticides, and collisions. The scale of threats is daunting, and the best available science shows that it is critical to protect the best of the remaining intact habitat, and then grow that habitat while protecting it from incursion by threats.

Recommendations

1. Utilize the Sagebrush Conservation Design and Threat-based Strategic Conservation to prioritize habitat investments within Oregon's sage-grouse range.
2. Engage in cooperative planning to develop a sage-grouse habitat spatial strategy based on both sage-grouse demographic information and habitat condition.
3. Prioritize addressing the primary threats of invasive annual grasses, conifer encroachment, and wildfires.
4. Conservation actions should focus on increasing overall carrying capacity of the landscape with a focus on adult hen, nest, and brood survival.