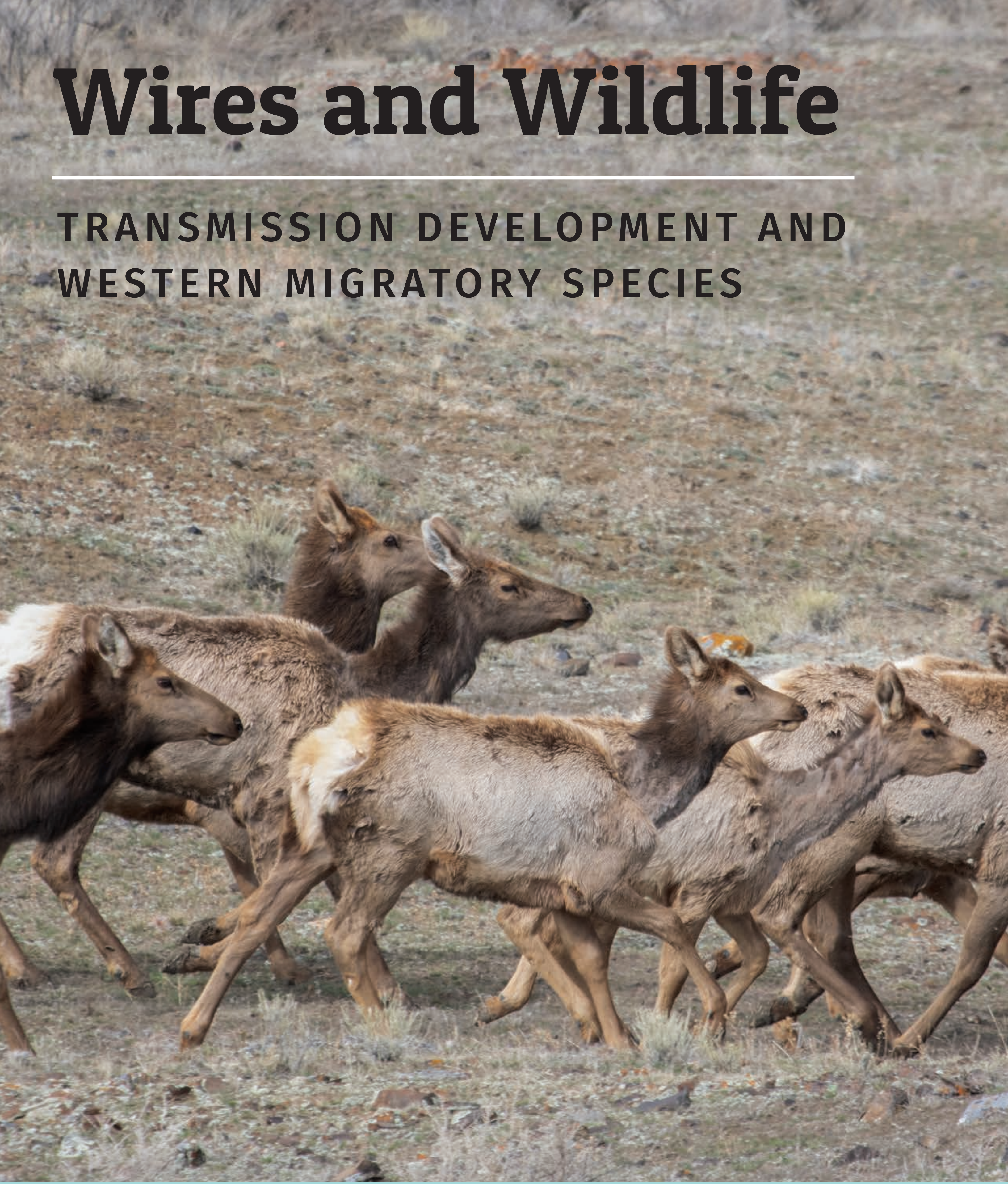
Wires and Wildlife

TRANSMISSION DEVELOPMENT AND WESTERN MIGRATORY SPECIES



NATIONAL WILDLIFE FEDERATION

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TRANSMISSION DEVELOPMENT AND WESTERN MIGRATORY SPECIES

Lead Authors: Andrew F. Jakes, Veronica Ung-Kono, and Edie Juno

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NATIONAL WILDLIFE FEDERATION

1200 G Street, NW, Suite 900

Washington, D.C. 20005

www.nwf.org

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Glossary

- **Abiotic:** All non-living factors that influence an ecosystem (i.e., water, soil, sunlight).
- **Adaptive management:** A flexible and science-based approach to support decision-making in the face of uncertainty that encourages "learning by doing," where data from monitoring and evaluation lead to iterative adjustments to future management and implementation efforts.
- **Anthropogenic climate change:** Climate change caused by human beings as the result of greenhouse gas emissions from the burning of fossil fuels, land-use change, and other activities.
- **Big game:** Colloquial name for animals, typically large ungulates, that are managed by wildlife agencies for harvest.
- **Biotic:** All living factors that influence an ecosystem (i.e., plants, animals, fungi).
- **Cumulative Effects:** The additive effects of anthropogenic disturbance on ecological processes and wildlife.
- **Ecological Connectivity:** A landscape-level characteristic that measures the movement of species (i.e., at the gene, individual, and population levels), as well as movement of other biotic factors like communities and nutrients across landscapes. The greater the ecological connectivity, the greater ability for an ecosystem to be properly functioning and resilient to fluctuating conditions.
- **Demography/Demographic:** The study of wildlife births and deaths, which influence population numbers.
- **Direct mortality:** Specific mortality events (e.g., wildlife-vehicle collision).
- **Ecological trap:** Perceived high-quality habitat by wildlife becomes dissociated from the species realized fitness
- **Environmental Justice:** The just treatment and meaningful involvement of all people, regardless of income, race, color, national origin, Tribal affiliation, or disability, in decision-making and other regulatory activities affecting human health and the environment. It ensures people are fully protected from disproportionate and adverse human health and environmental effects (including risks) and hazards, including those related to climate change, the cumulative impacts of environmental and other burdens, and the legacy of racism or other structural or systemic barriers; and have equitable access to a healthy, sustainable, and resilient environment.
- **Evapotranspiration rates:** Actual rate at which water vapor is returned to the atmosphere from the ground and by plants.
- **Free, Prior, and Informed Consent (FPIC):** FPIC is a specific right granted to Indigenous Peoples recognized in the UN Declaration on the Rights of Indigenous Peoples, which aligns with their universal right to self-determination. FPIC allows Indigenous Peoples to provide or withhold/withdraw consent, at any point, regarding projects impacting their territories. FPIC allows Indigenous Peoples to engage in negotiations to shape the design, implementation, monitoring, and evaluation of projects.
- **Focal species:** Species whose spatiotemporal requirements would envelope the needs of other species within an ecosystem and across scales.
- **Fuel aridity:** Dryness of the vegetation.
- **Hydroperiods:** Duration or timing of flooding in wetlands.
- **Indirect mortality:** Changes to the landscape that lead to a decrease in survivorship and recruitment in wildlife populations (e.g., increased stress, inaccessibility to quality forage).
- **Indicator species:** Species which can provide information on ecological changes and give early warning signals regarding ecosystem processes in site-specific conditions due to their sensitive reactions to them.
- **Interregional transmission:** Interstate transmission connecting RTOs/ISOs.
- **Linear features:** Both natural and human-made features that fragment the landscape. Examples include creeks, rivers, railways, fences, roads, and transmission lines.
- **Migration:** Seasonal round-trip movements between discrete areas not used at other times of the year by the individual.
- **Mutualistic:** A relationship between organisms, where each organism benefits.
- **Partial Migrations:** Where some individuals in a population migrate between distinct seasonal ranges, while others remain residential to one annual range.
- **Parturition:** To give birth to offspring.
- **Patch size:** The area of a relatively homogenous habitat that differs from surrounding habitats.
- **Renewable energy sources:** Includes resources such as onshore and offshore wind, solar and geothermal power.
- **RTOs/ISOs (Regional Transmission Organizations/Independent System Operators):** Independent organizations that coordinate, control and monitor the operation of the electrical power system.
- **Rut:** Period when ungulates are sexually active and mate.
- **Senescence:** The inability of cell division and growth in plants, culminating in plant deterioration.
- **Stopover sites:** Specific locations along a migration route where wildlife will rest or take advantage of high-valued resources.
- **Substation:** A high-voltage electric system facility where voltages are changed from one level to another and the type of current is also changed (direct to alternating or vice versa).
- **Synergistic effects:** Effects from multiple factors (e.g., stressors on wildlife) whose sum is greater than would be expected given their individual effects.
- **Ungulate:** Hoofed mammals.
- **Vapor pressure deficit:** A measure of how dry or how humid air is, this is the gap between how much water the air holds and how much it could hold at the same temperature.

Executive Summary

Ungulates and greater sage-grouse are among the many wildlife species that rely on seasonal habitats and the ability to migrate between these habitats to rear offspring, survive, and thrive. Wildlife habitat in the western U.S. is rapidly being transformed by human development. Climate change can further interfere with wildlife migrations and exacerbate the impacts of other human-caused disturbances and stressors such as habitat fragmentation and degradation.

To counter the effects of climate change, and account for an increasing human population, the United States must increase renewable energy generation and the capacity of energy transmission across long distances. The same states with low population densities and abundant wildlife also often hold significant potential for wind and solar generation. The power generated in these sparsely populated rural areas can be exported to densely populated urban areas, but doing so requires transmission lines.

Transmission lines often cross a variety of wildlife habitats and migration routes. Yet, the cumulative impacts of renewable energy generation, transmission development, and other stressors on wildlife behavior and habitats remain poorly understood. Transmission lines and other linear infrastructure may fragment and degrade habitat by impeding access to resources and disrupting migration routes for several Western wildlife species.

This report provides an overview of the threats facing some of these migratory species, in light of their unique habitat needs, in order to understand the potential implications of transmission buildout in the Intermountain West. We identify several ways that transmission development may affect species and valuable habitat, all in the context of ongoing global change. For ungulates, the impacts of transmission construction and development may largely resemble the impacts of roads and other types of human activity, exacerbating habitat degradation and loss. For greater sage-grouse, the impacts may be more significant, as evidence suggests the presence of transmission lines boosts predator populations and influences behavior. Through an extensive literature review, we also identified significant research and monitoring gaps that, if addressed, could inform siting and design of transmission development now and into the future.

To prevent unintended impacts to wildlife and communities, the National Wildlife Federation recommends minimizing "greenfield" transmission development in undisturbed and natural areas. Analysis shows that upgrading existing transmission infrastructure to increase capacity through grid-enhancing technologies, and the use of advanced reconductoring in existing rights-of-way, can help us meet needs – and do so cost effectively. Additional infrastructure can also be sited on lands that have already been disturbed or degraded.

Where new greenfield development occurs, the impacts on wildlife can be reduced when stakeholders come together to make evidence-based decisions about planning and siting. To make sense of large amounts of data and examine alternatives, we recommend the use of a dynamic decision-support tool. This tool could help to identify and prioritize important wildlife seasonal ranges and connectivity requirements for conservation and prudent management, thereby offering more certainty to industry and agencies alike. This decision support tool would help to evaluate and optimize identification of low-impact placements for current and future energy development, predicted wildlife distributions and movement requirements, and climate-related changes to habitats throughout the American West. As additional data is provided by stakeholders from research and monitoring efforts, the tool can be updated and further refined to meet user needs.

This report also provides examples of three smaller-scale success stories that offer insights and frameworks for proactively planned and responsibly sited transmission developments. Finally, we offer a range of recommendations and an adaptive management approach to guide industry and agencies within the Intermountain West on the path to responsible transmission development.

Photo: Faina Gurevich/Getty Images

Key Takeaways

- Thoughtful, data-driven decisions about infrastructure planning and siting can conserve wildlife habitat while building a connected Western transmission grid.
- Migratory wildlife species play an important role in the Intermountain West – and conserving their habitats can indirectly benefit other species and preserve Western culture.
- Land-use change, development, and urbanization are interacting with the effects of climate change, leading to unprecedented rates of change in Intermountain West ecosystems.
- The Intermountain West faces an array of impacts from human-caused climate change, including higher temperatures, extreme weather, reduced snowpack, intensified drought, and more frequent and extreme fires.
- Extensive human development and land use change across the West continue to drive habitat and fragmentation.
- Impacts from transmission lines and associated infrastructure may be direct or indirect, temporary or permanent, and can have localized and widespread effects on ecosystems.
- Disturbances and stressors related to land-use change and climate change can't be evaluated in isolation – these stressors can add up, and the effects can be challenging to predict.
- Many ungulates undertake migrations to exploit resources, tracking environmental cues and using routes passed down through generations.
- Changes in snowpack, drought severity, and other environmental conditions intensified by climate change could make migration riskier or less rewarding, but more research is urgently needed.
- Climate change threatens to intensify loss and degradation of the sagebrush rangelands upon which greater sage-grouse depend.
- Research examining the impacts of linear features can shed light on potential impacts from transmission line development on migratory species in the Western US
- Relatively little research to date has assessed the impacts of transmission lines on ungulates.
- A growing body of work suggests that transmission line development could pose serious risks to greater sage-grouse, by supporting predator populations and influencing sage-grouse behavior.
- More research is needed to improve our understanding of the impacts of transmission development on wildlife in the context of global change.
- The use of adaptive management, which entails learning by doing and adjusting management in light of new information, can also reduce negative effects of development on wildlife.
- We recommend the use of a dynamic decision-support tool (DST) that can help industry, state agencies, Tribes, communities, and others to avoid and minimize unintended impacts on multiple species and their habitat and identify optimal areas for conservation and development.

Introduction

Over the past century, the Intermountain West[1] has experienced rapid and extensive landscape-scale changes due to human development and climate change. Migratory wildlife face unique challenges, as they may be exposed to disparate changes across a large geographic area. Even if species can move and or adapt to a changing climate, there is no guarantee that new habitats will adequately support their populations for the long-term. Human development and disturbances along key migration routes – sometimes only a few hundred meters across – can impede movement and therefore have population-level consequences.

To mitigate the intensifying effects of climate change, the US must rapidly decarbonize with renewable energy generation, such as solar and onshore wind energy. Development of these renewable energy sources also requires the expansion of transmission networks across states and regions to bring electricity from generation sites to end users. In the US, the geographic locations with the greatest clean energy generation potential are located far from the population areas that depend on access to this electricity. As a result, the US will need to upgrade existing transmission lines and build interregional transmission lines.

Though the need to increase transmission capacity is urgent, progress is slow. There are more than 700,000 circuit-miles of transmission lines in the U.S.[2] In total, 3,300 circuit-miles were upgraded or built and energized annually.[3] During that same time, only 70 circuit-miles of interregional transmission were energized each year

Human development and disturbances along key migration routes – sometimes only a few hundred meters across – can impede movement and therefore have population-level consequences.

Photo: Jared Llyod/Getty Images

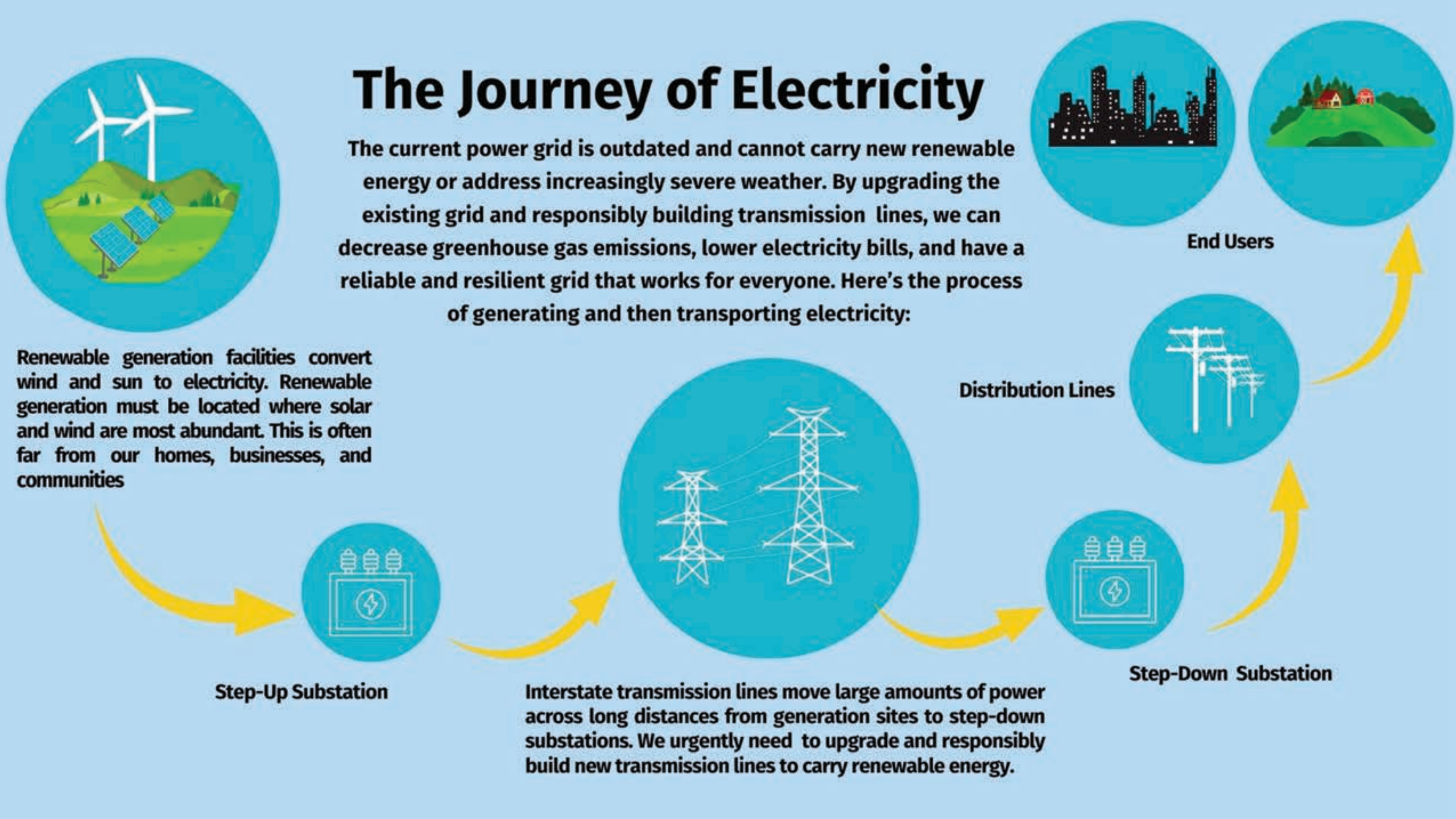

Figure 1. *A visual depiction of the power grid.*

Some forecasts suggest that to meet growing demand for energy and federal goals for decarbonization, regional transmission capacity must expand approximately 50 percent between 2030 and 2040.

from 2011 to 2020.[4] In the Intermountain West, the need for transmission lines that extend beyond the bounds of a singular state (interstate) and a regional transmission organization (RTO) or independent system operator (ISO) (interregional) arises from increasing load demand. Over the past two decades, traditional regional transmission planning has not produced a single interregional transmission line outside of California.[5] Outside of traditional regional planning groups, delays and cancellations have stymied proposals for new, interstate transmission projects.

As a result of climate change, increasingly severe weather continues to erode the reliability and resilience of the power grid, in addition to delaying federal and state clean energy policy goals. Western electricity markets will likely grow to over $40 billion per year in 2050.[6] Some forecasts suggest that to meet growing demand for energy and federal goals for decarbonization, regional transmission capacity must expand approximately 50 percent between 2030 and 2040.[7] However, with co-location and reconductoring, the US may meet as much as 85 percent of required line miles – quickly and cost-effectively.[8]

Conserving Wildlife and Connecting the Western Grid

Thoughtful, data-driven decisions about infrastructure planning and siting can conserve wildlife habitat while building a connected Western grid.

As with other types of infrastructure, transmission development affects ecosystems. In isolation, poorly sited lines could have both short and long-term impacts, as transmission towers built today may exist on the landscape for decades to come. Together with other human-created changes, cumulative effects, or the additive effects of anthropogenic disturbance on ecological processes and wildlife, may have far-reaching consequences. Using the best available science and technology to inform decision-making can dramatically reduce negative impacts on wildlife and ecosystem processes.

Current research and deliberations suggest that siting renewable energy and transmission in a way that reduces impacts on wildlife will not prevent the U.S. from reaching clean energy generation and transmission goals – to the contrary, it may be the most economical choice in the long run.[9] Without constraints on siting, development of renewable energy and transmission capacity could drive significant conversion and fragmentation. On the other hand, strong siting protections may virtually eliminate the need for land conversion in areas of high conservation value, including wildlife corridors.[10] An analysis published in 2023 found that such siting protections would increase the net cost of energy and transmission buildout in the West by approximately 3% – and these costs may be overestimated, as true costs of energy development in areas of conservation value were beyond the scope of the analysis.[11]

The responsible development of energy transmission for the 21st century balances social and ecological needs. It begins by upgrading the existing power grid's infrastructure with grid-enhancing technologies such as advanced conductors to expand capacity in existing rights-of-way (ROW) and building additional infrastructure on already disturbed or degraded lands where possible. Where new "greenfield" transmission infrastructure must be built, responsible development will entail thoughtful siting to avoid ecologically or culturally significant areas, coupled with locally informed mitigation measures. Ongoing monitoring of project impacts must inform best practices and support adaptive management. These considerations and approaches will be important as we account for Western habitats and culture.

Where new "greenfield" transmission infrastructure must be built, responsible development will entail thoughtful siting to avoid ecologically or culturally significant areas, coupled with locally informed mitigation measures.

The Importance of Ungulates and Other Migratory Species in the Intermountain West

Ungulates such as elk have held immense cultural significance for many tribes for millennia. Money spent on wildlife viewing and hunting finances natural resource management and stimulates rural economies.

Migratory wildlife species play an important role in the Intermountain West – and conserving their habitats can indirectly benefit other species and preserve Western culture.

The diversity of wildlife species that inhabit the rugged, breathtaking landscapes of the West have supported human populations for generations and have captivated people around the world for centuries. Ungulates such as elk have held immense cultural significance for many tribes for millennia.

Money spent on wildlife viewing and hunting finances natural resource management and stimulates rural economies. For example, Montana's natural landscapes bring tourists to places like Yellowstone National Park, Glacier National Park, and other outdoor attractions. In 2021, 12.5 million non-residents visited Montana and spent an estimated $5.22 billion.[12] According to a 2016 Montana Fish, Wildlife, and Parks survey, big game hunting in Montana produced 3,300 jobs and $324 million in expenditures annually (about $366 million in 2021 dollars).[13]

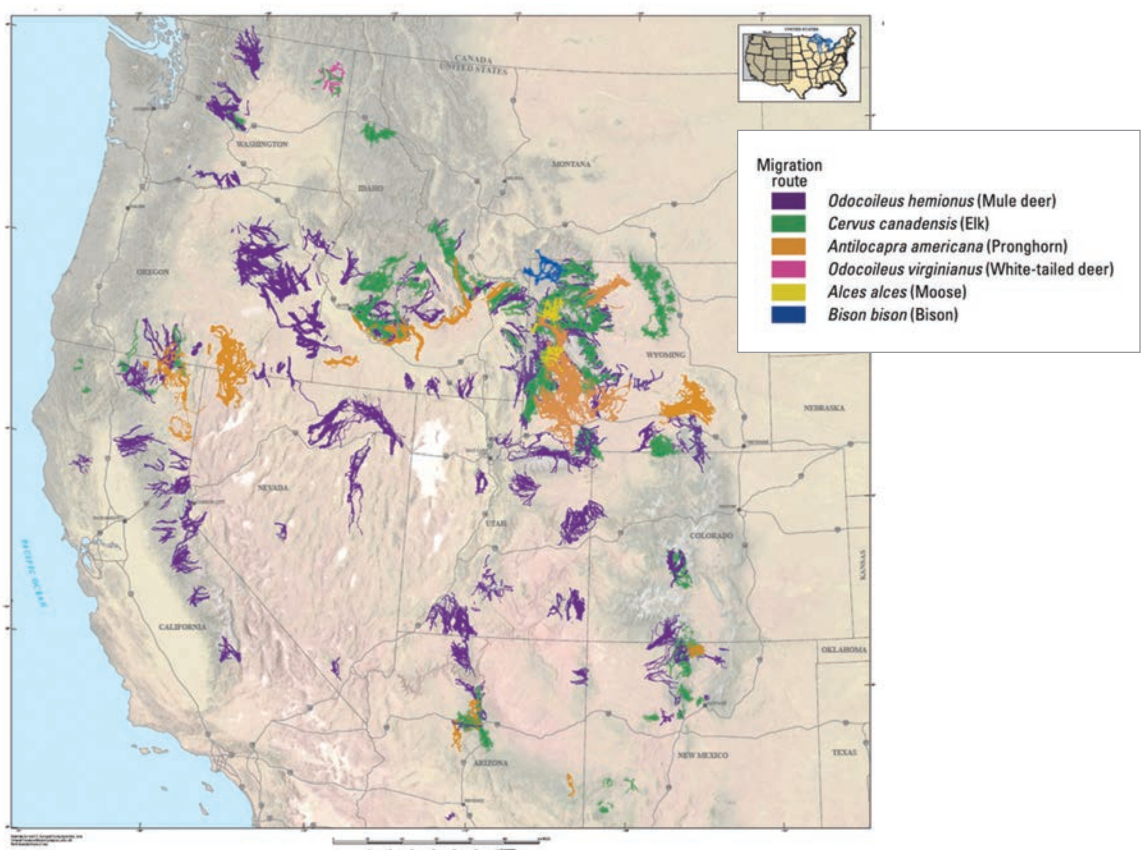

Figure 2. *USGS The migration routes of 182 unique herds mapped in the* US Geological Survey report series Ungulate Migrations of the Western United States *(Kauffman and others, 2020a, 2022a, c, 2024a).*

Conserving the West's Migratory Species and Connected Landscapes

To illustrate the challenges and opportunities of transmission development in the West, this report focuses on the potential impacts to a handful of charismatic, well-managed migratory species of wildlife: namely, **ungulates** – hoofed mammals including species such as elk *(Cervus canadensis)*, mule deer *(Odocoileus hemionus)* and pronghorn *(Antilocapra americana)* – and **greater sage-grouse (GRSG)** *(Centrocercus urophasianus)*. Though each species has specific biological adaptations and ecological requirements, these animals face many of the same threats, including habitat loss and degradation, shifting or declining resource availability due to climate change, and invasive species. For example, research indicates that fossil fuel energy development can affect behavior and population dynamics of both ungulates and GRSG.[18]

Understanding the impacts on migratory wildlife such as elk, pronghorn, mule deer, and GRSG can provide useful information for energy transmission planning efforts intended to identify and maintain connectivity throughout a system.[14] For populations to remain viable, many migratory animals need to access and move between multiple habitats that provide different resources. **Migration** is defined as seasonal round-trip movements between discrete areas not used at other times of the year by an individual.[15] Individuals in partially migratory populations of GRSG, for example, may travel to distinct habitats across the year for breeding, rearing young, and wintering while others remain in the same area year-round.[16] In the longest recorded GRSG migration, some individuals traveled more than 120 kilometers in each

Box 1. Why Does Ecological Connectivity Matter?

Ecological connectivity is a landscape-level characteristic that supports well-functioning and more resilient ecosystems. A larger, more intact, and better-connected system enables wildlife to track changes in seasonal conditions, find food in a larger area, return to or locate new breeding grounds, respond to unpredictable events, and adapt to human development. In general, human development can cause both **direct mortality** and **indirect mortality** of wildlife.[23] Indirect mortality can be due to behavioral changes (e.g., stress) that can decrease survivorship and recruitment, thereby affecting the long-term persistence of populations. Long-term studies are needed to fully assess the influence of incremental human development and disentangle their overall effects on wildlife populations.[24]

Ecological connectivity supports ecosystem function and helps to sustain wildlife populations under the Department of the Interior Secretarial Order 3362, "Improving Habitat Quality in Western Big Game Winter Range and Migration Corridors."[25] Order 3362 focuses on elk, mule deer, and pronghorn in 11 Western States. It directs the Bureau of Land Management (BLM), the U.S. Fish and Wildlife Service (FWS), the National Park Service (NPS), and the U.S. Geological Survey (USGS) to partner with State wildlife agencies on their priorities and objectives for identifying and conserving ungulate migration corridors and winter-range habitat.[26] States have also taken action: examples include Wyoming's Mule Deer and Antelope Migration Corridor Protection Executive Order,[27] New Mexico's Wildlife Corridors Act,[28] and California's Wildlife Connectivity and Climate Adaptation Act.[29] However, these policy efforts to conserve species habitats are only the beginning. The majority of ungulate migration routes remain unprotected, even as populations continue to decline.[30]

Photo: David Hoffman Photography/Getty Images

The movement patterns of these partially migratory populations more closely resemble that of ungulates than other bird species, as they move slowly through quality migratory route habitats and then pass quickly through areas with fewer resources.

direction annually between Canada and Montana.[17] The movement patterns of these **partially migratory** populations more closely resemble that of ungulates than other bird species, as they move slowly through quality migratory route habitats and then pass quickly through areas with fewer resources.[18] Research suggests that regionally widespread species are disproportionately significant in determining broad-scale habitat usage patterns.[19] Therefore, preservation of ungulates and GRSG migrations may serve as a proxy for maintaining effective **ecological connectivity** (see Box 1).

The **focal species** addressed in this report have resource needs – over space and time – that encompass the needs of other species at multiple scales of use.[20] Other practical reasons, such as specific funding requirements, collaborative opportunities, and monitoring protocols, can signal that one species may be chosen as an indicator of broader multi-species impacts. For example, GRSG has served as a prominent species for conservation planning in sagebrush rangelands across the West.[21] The GRSG may migrate relatively short distances between winter and summer ranges, but the partnerships and programs assembled for effective GRSG management can serve as a roadmap for big game (i.e., managed ungulates) conservation and management efforts. Since migratory wildlife require a range of habitats, they are particularly vulnerable to the detrimental impacts of climate change.[22] In response, Tribal and state wildlife agencies' conservation efforts have focused management efforts on the aforementioned focal species, as well as other ungulates, including bison *(Bison bison).*

Why Do Migrations Matter?

The loss or interruption of wildlife migrations could have cascading ecological effects. Large ungulates strongly influence the structure and functions of ecosystems across time and space, as they migrate to satisfy foraging and behavioral requirements.[31] Ungulates alter plant communities and stimulate plant growth, serve as prey for predators, and even influence fire regimes and nutrient cycling as they move across the landscape.[32] The next section outlines how climate change and human development are reshaping the Western landscape and how these stressors present new challenges for wildlife conservation.

Photo: Tanner Saul/NWF

Photo: Jordan Siemens/Getty Images

The Changing Intermountain West

Land-use change, development, and urbanization are interacting with the effects of climate change, leading to unprecedented rates of change in Intermountain West ecosystems.

Climate Change

The Intermountain West faces an array of impacts from human-caused climate change, including higher temperatures, extreme weather, reduced snowpack, intensified drought, and more frequent and extreme fires.

Increased atmospheric carbon dioxide levels, driven by the burning of fossil fuels, land-use change, and other human activities, have led to global average temperatures in the last decade that were approximately 2°F (1.1°C) higher than pre-industrial levels.

With these warmer temperatures come altered precipitation patterns and more frequent extreme weather events.[33] These changes influence how ecosystems function, where organisms are distributed, and how species interact with one another.[34] Without significant reductions in greenhouse gas emissions, the frequency and intensity of extreme weather events will continue to increase and global mean temperatures will continue to rise as the result of **anthropogenic climate change.**[35] Limiting warming to 1.5°C could significantly reduce impacts on both ecosystems and human communities when compared to increases above 2°C – and staying within this limit requires significant expansions in renewable energy generation.[36]

Already, the average surface temperature of the US has increased more quickly than the

With these warmer temperatures come altered precipitation patterns and more frequent extreme weather events.

Photo: Mark Newman/Getty Images

Climate impacts will vary regionally across the country, but the Intermountain West will encounter particularly challenging conditions. For example, Montana and Wyoming are traditionally known for climate extremes and seasonal variability, but climate change will intensify these conditions.

average global temperature.[37] Effects include alterations to precipitation patterns such as reduced snowpack distribution, a greater proportion of rain compared to snow in winter, more frequent and intense extreme rainfall events, and decreased overall rainfall in summer. The outcome of these changes in precipitation patterns include increased duration, frequency, and severity of drought coupled with longer fire seasons and more intense wildfires.[38]

Climate impacts will vary regionally across the country,[39] but the Intermountain West will encounter particularly challenging conditions. For example, Montana and Wyoming are traditionally known for climate extremes and seasonal variability, but climate change will intensify these conditions. The region is already experiencing climate impacts, including severe drought, increased size and frequency of hail, larger wildfires, rising temperatures, and increasingly erratic precipitation patterns.[40] Washington, Oregon, and Idaho will be challenged by changes to frequency and intensity of extreme precipitation events, decreased snow accumulation, accelerated snowmelt, more variable annual precipitation, and record-breaking high temperatures.[41] Hotter temperatures and drier summers have already increased the extent and intensity of wildfires and duration of the fire season in the region, and experts expect this trend to continue.[42] Finally, Nevada, New Mexico, Utah, and Colorado will continue to be challenged by changes to surface and groundwater availability, increased drought and aridification, and more frequent extreme precipitation events that contribute to dangerous flooding.[43] Positive feedback loops have reduced snowpack and the region is projected to see additional and more frequent low-snow years under a warming climate.[44] Box 2 illustrates some of the impacts to these resources already experienced by Westerners.

Increased temperatures and an increased **vapor pressure deficit** from anthropogenic climate change have already been linked to increased fuel aridity, increased area of forest burned, and increased percentage of area experiencing high-severity fire in the West, with trends likely to continue.[45] Coupled with, and amplified by other stressors, the effects of climate change can drive transformational – and sometimes abrupt or even irreversible – changes in ecosystems, including unnatural transitions from one ecosystem to another (e.g., from forest to grassland).[46] Compounding events, such as an extreme heat wave during a severe drought, can have devastating impacts on both human communities and ecosystems – and climate change is increasing the risk of such events.[47]

Shorter, warmer, and often wetter winters can be a boon for some invasive species as well as some native pests and pathogens.[48] Invasive annual grasses such as cheatgrass *(Bromus tectorum)* and bluegrass *(Poa pratensis)* are expected to further expand in a hotter, drier, and more fire-prone future.[49] These invasive grasses displace important native grassland species, with cascading impacts across food webs, and can increase flammability to ecosystems, ultimately leading to increased risk of fire.[50] Species of both native and non-native plants that provide forage for wildlife may benefit from climate change, as plant growth increases with warmer temperatures and higher atmospheric CO2 levels; however, some of these gains may be negated by drought stress.[51]

It's clear that climate change threatens both human communities and biodiversity. But in addition to pronounced changes to environmental gradients, the West continues to experience a dramatic increase in human-induced development.

Anthropogenic Development in Western US

Extensive human development and land use change across the West continues to drive habitat loss and fragmentation.

The Intermountain West is endowed with rich and diverse natural resources: open range grasslands, vast forests, high-volume freshwater rivers, and expansive deposits of natural gas, oil, coal, and precious minerals. In recent decades, the population of the Intermountain West has grown rapidly. Many hope to escape populated city centers and find serenity

Box 2. NWF Stories of Climate Change in the Intermountain West

NWF Climate Chronicles: NWF Director of Sporting Advocacy Aaron Kindle is a lifelong hunter and angler. He has lived throughout the West his whole life, including Colorado, Wyoming, and Montana:

Hunting and fishing with my kid is the pinnacle of a life experience. I have a lot of concerns with the future, when I think about his opportunities... When we are thinking about climate change and habitat loss and all these things that seem to be accelerating, I'm really concerned and I feel this sense of urgency to take care of it and recruit the sporting community.

"We're seeing things like hotter temperatures in the summer. So hot, it's not ethical to fish for trout in the afternoons anymore. Around Colorado and the rest of the West, we saw so many fishing closures last year because the water was too hot to fish."

NWF Climate Chronicles: Adam Shaw, Missoula MT, Sportsman:

"I grew up going hunting and fishing with my dad and my uncle and my grandfather. So for me to be able to pass on that tradition, that legacy to my boys, it's one of the most important things in my life. Climate change is important for me because we are seeing changes in the recreational opportunities we have as hunters and anglers. It's more about protecting the environment so that these kids, what we leave when we are gone, is in better shape than what we inherited."

A Hunter and Angler's Guide to Climate Change: Challenges, Opportunities, and Solutions describes how Don Sampson, chief of the Walla Walla Tribe and member of the Confederated Tribes of the Umatilla, has been working to restore watersheds in the Pacific Northwest:

As a hunter and angler, Sampson has witnessed first-hand the devastating impacts that climate change has had on the lands, waters, wildlife, and Indigenous people. "For 20 years we've seen snowpack decline and that affects the spring waters that allow chinook salmon and sockeye to migrate up river...We're seeing catastrophic fires that are 5 or 10 times greater than in the past. The fires destroy habitat for elk, moose, caribou, and bighorn sheep. We depend on these species for food and for our ceremonies." Sampson says that hunters also see bluetongue disease in white tail deer, which is nearly always fatal. The disease is exacerbated by the drought conditions of the West. "Five years ago, we hadn't seen bluetongue disease. [In 2020] we lost 93% of deer in one part of our reservation because of bluetongue."

Photo: Steve Hockstein Bloomberg/Getty Images

Despite the abundance of public lands (in the Intermountain West), the majority of lands are privately owned, particularly within intermountain valleys and along rivers and streams, which are quickly being developed.

in small communities and enjoy the proximity to the outdoors.[53] With denser populations, the Intermountain West landscape and culture are changing dramatically. Despite the abundance of public lands, the majority of lands are privately owned, particularly within intermountain valleys and along rivers and streams, which are quickly being developed. Changes in population densities drive direct habitat losses from the land conversion.

Today, habitat loss from land-use change remains the leading global driver of biodiversity loss, followed by overexploitation of natural resources.[54] In addition to the development of human settlements and urbanization, agriculture, ranching, mining, and development of oil and natural gas may drive such conversions.[55] In addition, **linear features** such as roads, fences, railways, pipelines, transmission lines and canals, are increasing and typically co-located with one another. Although co-location of infrastructure can minimize land disturbances, the development of this infrastructure fragments and degrades landscapes. This can cause a decrease in **patch size,** facilitate the spread and establishment of invasive species, alter hydrology, and impede or completely block wildlife movement.[56]

Prime areas for human development often overlap with important wildlife habitats. Lower elevation intermountain valleys are most often where ungulates overwinter, to find forage and escape deep snow. Valleys are also hotspots for new housing development. Roads and other linear infrastructure associated with development decrease ecological connectivity by presenting major barriers to movement, making it difficult or impossible for wildlife to move between habitat patches, even when separated by short distances.[57]

Transmission Lines, Rights-of-Way, and Other Associated Infrastructure

Impacts from transmission lines and associated infrastructure may be direct or indirect, temporary or permanent, and can have localized and widespread effects on ecosystems.

Building interstate transmission lines requires large-scale construction projects in long, linear corridors, sometimes spanning hundreds of miles. In general, there are two options for building transmission lines: aboveground lines with tall support structures, or belowground (i.e., buried) cables. Lines in the Intermountain West and Southwest regions are generally above ground, as the region's shallow bedrock makes burying cables challenging and costly.[58] Construction of both belowground and aboveground power lines creates a right-of-way (ROW) that is often altered during construction and continuously managed throughout operations. Upgrading transmission power lines also involves upgrading or building new substations within heavily fenced areas adjacent to the ROW.

As with other types of development, transmission lines may directly or indirectly affect habitats, landscapes, and species during the construction, operation, and maintenance phases of a project. Such effects may be temporary or permanent. Direct and indirect impacts from transmission lines may stem from:

- Vegetation removal and soil disturbance (possible introduction of invasive species, altering competition between species)
- Habitat conversion and fragmentation, with transmission corridors potentially creating an impediment to movement
- Electromagnetic radiation emitted by power lines, the effects of which are still being studied
- Collisions and electrocutions for aerial animals, with some species more vulnerable than others
- Noise, light, and increased human activity, particularly during construction and maintenance
- Increased recreational use of the area (e.g., when maintenance roads are used as hiking trails or off-road vehicles are driven on ROWs)
- Hydrological alterations, including related to removal of tree cover
- Edge effects, resulting from the abrupt transition between two distinct habitats, to the detriment of some species and benefit of edge species
- Barrier effects, when managed ROWs impede the movement of some species
- Creation of ecological traps, or inferior habitats that are preferred by species as the result of rapid environmental change[59]
- Alteration of interactions between species, including competition and predator-prey dynamics
- Beneficial habitat creation (e.g., when corridors with regular vegetation management creates underrepresented early seral habitat, which forms after disturbances, and which can be managed as stepping stones or corridors)
- Increased human activity and disturbance, which may influence animal behavior and spread of invasive plant species into ungulate habitat[60]

Construction of both belowground and aboveground power lines creates a right-of-way (ROW) that is often altered during construction and continuously managed throughout operations.

In a comprehensive study on a variety of taxa, researchers conducted a systematic review of both published and gray literature to assess possible influences from transmission line development on wildlife, communities, and ecological relationships.[61] They found that the timing of development (i.e., construction vs. operation phase) was a key factor in how transmission lines influenced abiotic conditions that could affect ecological processes, wildlife use, and **demography**.

The most obvious wildlife impacts generally occur along the transmission line ROWs, where regular maintenance occurs to maintain access and reduce risks to infrastructure from overgrown vegetation.[62] As an example, ROWs influence risks related to wildfire. Power lines can ignite wildfires when wildlife or vegetation make contact with power lines or when extreme weather compromises infrastructure. Interactions between wildlife and electrical infrastructure may also create serious and costly disruptions for energy consumers and damage infrastructure, with implications for public safety.[63] Between 2014 and 2018, wildland fires ignited by avian electrocution were documented on 44 occasions in the contiguous US, concentrated in the West.[64] However, because transmission lines are less likely to be buried underground or insulated, carry higher voltages, and traverse remote areas of the country, they are less likely overall to cause ignitions than lower voltage but much more common distribution lines.[65] In some environments such as forested or shrub ecosystems, well-maintained transmission ROWs act as fuel breaks and access routes for wildland firefighters.

Between 2014 and 2018, wildland fires ignited by avian electrocution were documented on 44 occasions in the contiguous US, concentrated in the West.

The presence of power lines and their ROWs may influence the relationships between predators and their avian prey, though responses of predators to infrastructure and landscape features are typically species-specific.[66] Some species respond with behavioral changes. For example, federally endangered whooping cranes *(Grus americana)* often avoid using stopover sites within 2 kilometers of power lines in non-drought conditions.[67]

High-voltage transmission development from renewable energy sources requires construction of **substations** to adjust line voltages for connections to distribution networks or renewable energy sources themselves. The construction of **renewable energy generation** and substations increases the total footprint and potential impacts of transmission development. Renewable energy generation sources and substations can have disproportionate impacts relative to their disturbance footprints since these features are generally contained within tall exclusion fencing and are concrete or gravel pads that are devoid of vegetation. These construction methods may keep wildlife away from substation infrastructure, yet some interactions remain unavoidable.[68] As a result, the existence of barriers, such as exclusion fencing, can alter wildlife movements and habitat use.

Most wildlife research on renewable energy has assessed wind turbine siting and impacts, particularly bird and bat mortality related to collisions.[69] These structures also emit noise and may entail substantial disturbance, which translates to habitat loss or degradation that affects ungulate and GRSG resource use or migration.[70] A rapidly growing body of research has also examined solar photovoltaic (PV) development's potential impact on wildlife movements and ecological processes.[71] For example, research from 2022 indicated that construction of solar arrays surrounded by impermeable security fencing resulted in the loss of high-use seasonal pronghorn habitat and created barrier effects in Wyoming.[72] In areas with continued development, native and diverse habitats continue to be converted, degraded, and fragmented at disproportionate rates.

Cumulative & Synergistic Effects

Disturbances and stressors related to land-use change and climate change can't be evaluated in isolation – these stressors can add up, and the effects can be challenging to predict.

Little is known about how stressors from development and climate change will combine or interact to influence wildlife behavior, habitat use and movement. For example, initial evaluations of an individual project such as a transmission line may suggest few impacts on wildlife. However, in concert with other landscape changes (i.e., roads, fences, cultivated areas), the impacts from climate change and development can have **cumulative (or additive) effects** on ecosystem level processes. Incremental changes from anthropogenic development, whether from the overarching changing climate or from a specific development type, place increased pressures on our ecosystems and the wildlife that depend on them. In addition, cumulative effects may have varying degrees of influence based on spatial and temporal considerations. For example, when climate impacts were included in predictive scenario modeling, a greater proportion of migratory habitat was lost compared with seasonal range habitat for pronghorn across the U.S. Great Basin.[73]

Photo: David McGown/Getty Images

Furthermore, stressors and disturbances may interact with one another and intensify impacts. As the pace of global change accelerates, understanding the **synergistic effects** (or interactions, with a combined effect greater than the sum of the individual effects) of stressors such as land-use change, climate change, and habitat fragmentation becomes more important than ever.[74] In these cases, the effect may be greater than would be anticipated. The synergistic effects of stressors on wildlife and its habitat will be scale dependent and may be challenging to predict. A growing body of research suggests that exposure to multiple, cumulative global stressors (climate change and land-use change) may accelerate loss of biodiversity and wildlife population declines.[75]

The following section provides an overview of the impacts of climate change and human development to migratory species. More research to understand cumulative and synergistic impacts is urgently needed, though assessment of such effects on wildlife remains methodologically challenging.[76]

As the pace of global change accelerates, understanding the synergistic effects (or interactions, with a combined effect greater than the sum of the individual effects) of stressors such as land-use change, climate change, and habitat fragmentation becomes more important than ever.

Summary of the Science: Climate Change and Development Impacts on Migratory Species of the West

Across multiple big game species, populations have shown migration route fidelity that has been passed down through generations using the same route every year, despite impediments to movement.

Migrations allow wildlife to exploit resources across time and space. Expanding human development across the West has made it increasingly difficult for migrating wildlife to adequately respond to naturally changing conditions. In particular, linear features can be difficult or impossible to negotiate. The following review of the current science focuses on a handful of focal species (ungulates and GRSG) that migrate between seasonal ranges to complete annual life-cycle requirements.

Understanding Long Distance Migration

Many ungulates undertake migrations to exploit resources, tracking environmental cues and using routes passed down through generations.

Long-distance migrations inspire awe and fascinate us. However, around the world today, these migrations are imperiled.[77] Wildlife seasonal migrations are generally in response to environmental changes such as precipitation patterns, forage productivity, or amount and quality of food.[78] Migrations are also influenced by biotic factors such as inter- and intraspecific competition, predator-prey dynamics,[79] or anthropogenic development, as well as genetically inherited traits and social learning.[80] Along the migration route, wildlife may use **stopover sites** to rest or take advantage of particularly high-value resources in addition to matching migration with improving forage conditions, as they move between **summer ranges** and **winter ranges**.[81] Across multiple big game species, populations have shown migration route fidelity that has been passed down through generations using the same route every year, despite impediments to movement.[82] Information about migration routes is socially transmitted, and this accumulated information is vulnerable to loss.[83]

Many ungulate populations in the Western U.S. are considered partially migratory, with some individuals migrating while others either remain year-round residents on one range and others using a mixture of movement tactics.[84] Individuals may switch movement tactics over their lifetimes or year to year.[85] Migratory behaviors may be more rigid in some species (such as mule deer) than others (such as pronghorn).[86] Many Western U.S. ungulate populations depend upon migration as a strategy for overall population persistence.[87]

In the Western U.S., ungulates can typically be found in larger numbers on winter ranges that provide sufficient food for grazing and minimize energy expenditure for survival.

As spring arrives and snowmelt occurs, ungulates may be cued to migrate. Some individuals undertake slower-moving spring migrations to “surf” the green-wave of emergent, protein-rich vegetation to take advantage of its nutritional content in preparation for **parturition**.[88] Others “jump” the green-wave and follow snowmelt so as to arrive on fawning or calving grounds before the peak of green-up so that offspring have the most nutritional forage available.[89] Once females reach these desired fawning or calving grounds, ungulates give birth in late-spring to early-summer. While on summer range, forage quantity peaks and ungulates forage on diverse vegetation to grow and store fat. Late summer into fall brings the onset of the **rut** and when North American ungulates reproduce. Fall vegetation **senescence** and changing conditions is believed to trigger ungulate migration.[90] In response, ungulates will undertake rapid-moving seasonal migrations to reach their winter range.

Photo: aydinmutlu/Getty Images

Ecosystem shifts driven by climate change or continued human development could narrow or even eliminate these critical linkages that connect seasonal ranges.

Bottlenecks are areas where migration routes narrow considerably as the result of topography, dominant vegetation, bodies of water, or human development.[91] Ecosystem shifts driven by climate change or continued human development could narrow or even eliminate these critical linkages that connect seasonal ranges.[92] In the Greater Yellowstone ecosystem, some bottlenecks used by pronghorn in long-distance migrations narrow to as little as 100 meters at times, constricted by roads, water, and sandstone cliffs.[93] Some of these routes have been used for thousands of years. These key linkages are threatened by becoming severed by roads and other linear features.

Climate Change Impacts on Ungulates

Changes in snowpack, drought severity, and other environmental conditions intensified by climate change could make migration riskier or less rewarding, but more research is urgently needed.

The effects of climate change on wildlife can be both short and long-term, but overall are expected to increase exposure to conditions that exceed physiological tolerance levels. There are also indirect effects to ecological processes, such as disruptions in predator-prey, competitor, and **mutualistic** interactions within and across communities. In the short-term, climate change may affect access to key resources and habitat. Over the long-term, areas formerly suitable as habitat may become unsuitable. Extreme weather, drought, and compounded events exacerbated by climate change may alter or degrade important wildlife habitat. In response, species may move to more favorable ranges (i.e., by moving upward in elevation or poleward) and find refuge from fleeting conditions.[94] Yet, evolution may play a role, as some species rapidly adapt to novel conditions.[95] Not all species will be able to shift their range or adapt, especially species with low dispersal ability.

The effects of broad-scale factors, like increased pressures on ungulates seasonal habitat use, are becoming more apparent on migrations.[96] Climate conditions modulate migratory behavior and population dynamics both directly and indirectly, and may be additive with other anthropogenic stressors.[97] Climate change can create mismatches between ungulate migrations and plant phenology, or timing in annual life cycles.[98] This is a particularly long-term problem for species like mule deer which demonstrate less behavioral plasticity and greater migration route fidelity when compared to other migratory ungulates.[99]

Snowpack across much of the Western US has steadily declined over the past 75 years and will likely continue to decrease over the course of this century.[100] However, warming temperatures and variability in precipitation regimes will likely increase across the Western states, and variability in severe snow conditions will either continue or increase.[101] During winter, the variability of precipitation type and severity can impact ungulate populations. For example, icy conditions can decrease forage access to ungulates, causing starvation and mortality.[102] Severe and variable snow conditions have led to extreme die-offs like with the northern populations of pronghorn.[103] Such conditions may force big game species to alter migrations and travel further distances to access open forage, thereby expending important energy reserves.[104] Indeed, continued fluctuations in winter-like conditions make it riskier for ungulates to migrate, therefore decreasing benefits to this movement tactic. Increased temperatures and decreased snowpack during winter may favor some species over others, thereby altering ecological communities. As an example, white-tailed deer *(Odocoileus virginianus)* populations across the U.S. Midwest respond favorably to these conditions. In contrast, moose *(Alces alces)* in this region become physiologically stressed from temperature increases and reduced snowpack.[105]

Increased temperatures can exacerbate drought conditions across the year, particularly during summer months and into fall. Drought can have significant impacts on ecosystem function including decreased **evapotranspiration rates**[106] and decreased **hydroperiods** in aquatic systems.[107] For big game species, high-moisture forage is an essential source of water, and drought conditions can lead to malnutrition, dehydration and death.[108] During migratory periods, drought has been shown to decrease spring green-up days, which can alter the "green wave" of vegetation and make it harder to find nutrient-dense forage.[109] Researchers have found that drought led to a decrease in pregnancy rates in migratory elk, which indicates that drought can reduce migration's nutritional benefits.[110]

The effects of climate change on wildlife can be both short and long-term, but overall are expected to increase exposure to conditions that exceed physiological tolerance levels.

These rangelands have already been dramatically altered and reduced by development, introduction of invasive plant species, overgrazing by livestock, deviations from historic fire regimes, encroachment by trees, fragmentation, and other human pressures.

Photo: Maria Jeffs/Getty Images

Rising temperatures and increasingly erratic precipitation patterns have resulted in a dramatic increase in the intensity and longevity of wildfires and the expansion of invasive species across the West. Earlier spring snowmelt has also led to increased fuel aridity, which favors fire conditions.[111] The positive feedback loop created when fire-tolerant invasive species, like cheatgrass, outgrows native species has changed vegetation composition and structure across Western rangelands. It has also damaged native shrubs used by ungulates for forage and cover.[112] Though low-intensity burns can add nutritional elements to soil and stimulate vegetation succession, fires may also reduce cover for big game calves and fawns, leaving them vulnerable to predation.[113] This may be particularly true in areas where intense wildfires have occurred, offering little to no nutrient return into the soil, thereby decimating the potential for rapid return of vegetative cover. One Western study examined how climate conditions affected the timing of elk migrations over six years. Results indicated that elk adjusted their migration timing to match changing environmental conditions, including earlier snow melt, earlier spring green-up, and changes in snow accumulation.[114]

A recent systematic review of research on the effects of climate change and climate variability on ungulates found relatively few articles addressing changes on ungulate migration and long-term research[115] on a variety of ungulate species studied. For example, relatively few studies have explored the effects of climate change on pronghorn, among other western ungulate species.[116] Many questions remain, and more research is needed to inform decision making.

Climate Change Impacts on Greater Sage-Grouse

Climate change threatens to intensify loss and degradation of the sagebrush rangelands upon which greater sage-grouse depend.

Many of the threats described above also apply in GRSG habitat. The GRSG inhabits ecosystems dominated by sagebrush *(Artemisia spp.)*. These rangelands have already been dramatically altered and reduced by development, introduction of invasive plant species, overgrazing by livestock, deviations from historic fire regimes, encroachment by trees, fragmentation, and other human pressures.[117] Alongside the GRSG, approximately 350 species of conservation concern in the US depend upon sagebrush habitats.[118]

As with ungulates, the impact of climate change on habitat use or population dynamics on GRSG remain underexplored.

Modeling suggests that in combination with other stressors, climate change will likely reduce habitat for GRSG in the Northern Rockies.[119] Although sagebrush rangelands are characterized by periodic fire, more frequent and intense wildfires can promote conversion of sagebrush habitat into systems dominated by invasive annual grasses, and these flammable grasses can in turn promote wildfire, creating a positive feedback loop capable of degrading or eliminating key habitat in some cases.[120] In addition, GRSG are highly sensitive to temperatures. In warmer parts of their range, like the Columbia Basin in Washington, climate conditions likely will reduce habitat quality, fragment populations and reduce connectivity for remaining GRSG populations.[121]

Linear Features and the Influence on Ungulates

Research examining the impacts of linear features can shed light on potential impacts from transmission line development on migratory species in the Western US.

Linear features are natural (e.g., rivers and streams) or human-developed (e.g., roads, utility corridors, fences, and railways) elements of landscapes. Ungulates can exhibit both positive or negative responses to such features, depending on the species, the ecosystem, and seasonality. For example, pronghorn use habitat along large rivers and streams to move from North to South during fall migration in their northern range.[122]

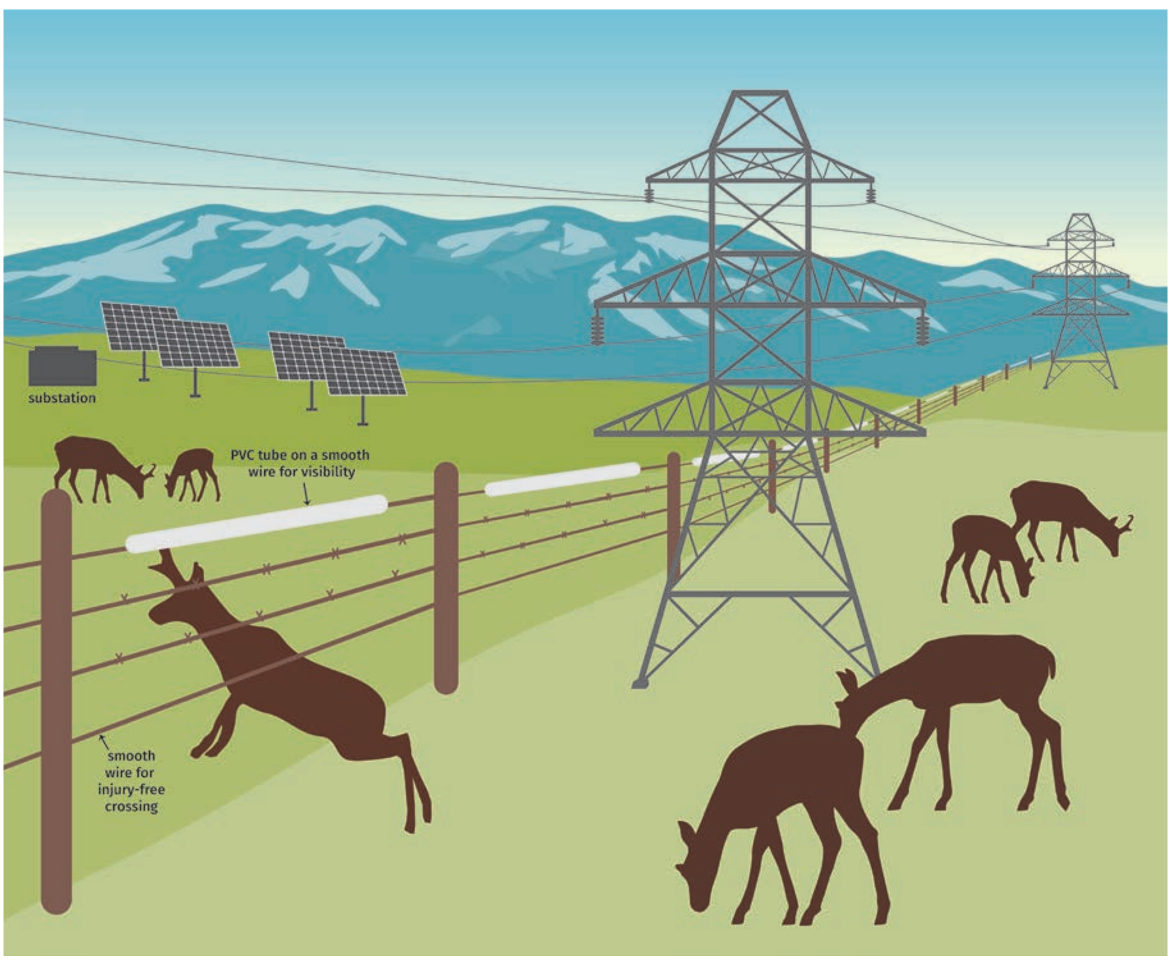

Figure 3. *A visual depiction of the scope of transmission infrastructure's impact and how pronghorn can co-exist with this infrastructure.*

Linear features can have both ecological and behavioral consequences on ungulates, particularly when they occur alongside other developments and infrastructure.

Human-made linear features can act as semi-permeable or impermeable (i.e., complete) barriers to ungulate movement, impeding access to key resources.[123] This, in turn, has consequences on ungulate reproduction and mortality rates.[124] Typically, linear features are found in combination with other anthropogenic developments, such as fences along farmlands[125] or transmission lines or roads associated with energy generation infrastructure.[126]

Linear features can have both ecological and behavioral consequences on ungulates,[127] particularly when they occur alongside other developments and infrastructure. Large roads and fences may block wildlife from accessing high-quality forage on seasonal ranges, leading to demographic consequences.[128] Roads and fences may pose risks that lead to delays in migration, creating temporal mismatches for optimal forage intake by ungulates.[129] On the other hand, ungulates may move more quickly through areas with human development and activity, which could create mismatches between ungulate location and plant phenology.[130] Some anthropogenic features may not act as impermeable barriers in isolation, but may alter ungulate behavior above certain densities, discouraging them from using areas as stopover sites or migratory routes.

Figure 4. *Pronghorn in New Mexico find limited shade under the shadow of a transmission pole. Photo: Wildlands Network*

Linear features such as roads and fences can also cause injury and mortality to big game from entanglement or vehicle collisions.[131] Roads alter relationships between species, including competition among plant species, by creating frequently disturbed environments favorable to invasive species and introducing plant propagules.[132] Finally, linear features may facilitate the movement of ungulate predators in certain landscapes.[133] For example, caribou *(Rangifer tarandus)* may use roadways and transmission ROWs for daily movements, but these features may also facilitate movement of wolves *(Canis lupus)*, thus altering predatory interactions.[134]

Transmission Line Impacts on Ungulates

Relatively little research to date has assessed the impacts of transmission lines on ungulates.

Though the impacts of transmission line development on big game movements and migrations are not yet well understood, some research has been conducted, most notably in Scandinavian countries. These studies assessed the influence of transmission lines on ungulates and indicate that species may either avoid or be attracted to these features, based on several factors. Depending on the species, transmission lines can deter habitat use and displace movement due to noise, alterations in the immediate electromagnetic field, visual distractions, changes in vegetation or canopy cover, creation of habitat edges, or an increase in predation risk, each of which may influence social behaviors and have demographic consequences.[135] Still, these alterations could also facilitate movement and encourage animal usage by providing novel habitat and desirable vegetation – in other words, they may serve as habitat corridors.[136]

When it comes to ungulates, evidence suggests that context matters: for example, researchers found that moose in central Norway did not avoid crossing transmission lines, unless located along steep gradients, yet found that when located along roads, power lines could act as a barrier to movement.[137] Other potential impacts of transmission lines on resource use and social dynamics by ungulates, such as caribou, including those related to noise, are poorly understood and warrant more exploration.[138]

In the Western US, we found one reference that recorded transmission line development influences on ungulates. The researcher observed that bighorn sheep (Ovis canadensis), moose and elk bedded down within transmission line rights-of-way, with vegetation types influencing use.[139] This report also observed that most attempts by elk to traverse transmission line ROWs were successful and that even an elk with calves traveled along the right-of-way. The report also indicated that transmission lines with accompanying roads provided increased access for hunters.

In addition to reviewing the peer-reviewed literature, Western wildlife managers and experts were interviewed for this section of the report, to better understand the relationship between transmission line development and ungulate movements. From these interviews, it does not appear that transmission lines themselves significantly influence ungulate behavior. Yet, expert opinions varied: transmission line ROWs could act as possible attractants (ungulates may see benefits from the vegetation change and opportunities to travel through these areas) or could encourage avoidance (ungulates will not use more open areas). There was, however, broad consensus that more research in this realm is required, and the value of data from long-term ungulate collaring and monitoring was emphasized. These data should inform regional planning and siting practices to help reduce impacts on prime wildlife habitat and working lands.[140]

Transmission Lines and Greater Sage-Grouse

A growing body of work suggests that transmission line development could pose serious risks to greater sage-grouse, by supporting predator populations and influencing sage-grouse behavior.

Evidence indicates that GRSG may be negatively affected by the presence of fossil fuel energy infrastructure[141] and to a lesser extent wind turbines or solar farms[142] by reducing nest or brood survival and habitat use.[143] A growing body of evidence also suggests that the development of

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Research indicates that GRSG avoided habitats near transmission lines because of their association with the abundance of the common raven, a native corvid known to predate GRSG nests and chicks.

transmission infrastructure could place additional pressure on GRSG population connectivity and indirectly lead to impacts on GRSG behavior, reproductive success, and survival.[144] For example, research in Wyoming identified that over a 6-year period, development of a 230 kilovolt transmission line had negative effects on GRSG habitat selection and survival overall, though the magnitude of the effect varied with habitat quality.[145]

Research indicates that GRSG avoided habitats near transmission lines because of their association with the abundance of the common raven *(Corvus corax)*, a native corvid known to predate GRSG nests and chicks.[146] The presence of ravens may also disrupt lekking (i.e., display and courtship behavior by males).[147] These generalist predators are "subsidized" by anthropogenic structures and have increased significantly in abundance in recent decades as a result.[148] Impacts on reproductive success of GRSG can extend up to 12.5 kilometers (roughly 8 miles) from the transmission line while habitat avoidance has been documented up to or beyond 10 km (roughly 6 miles) from power lines.[149]

In transmission corridors, evidence to support predator control measures is mixed, as is evidence on the efficacy of predator deterrents.[150] Habitat management and mitigation efforts, however, can provide cover for adult GRSG and their young, and have been shown to reduce nest predation and increase reproductive success.[151] For these reasons, management agencies should assume a variety of siting recommendations, including a conservative disturbance radius of 10 kilometers when planning new power lines, avoiding critical habitat, burying lines where feasible, and co-locating infrastructure whenever possible to reduce the total development footprint.[152]

Photo: milehightraveler/Getty Images

Photo: Tanner Saul/NWF

Knowledge Gaps, Data Accessibility Constraints, and Collaboration

More research is needed to improve our understanding of the impacts of transmission development on wildlife in the context of global change.

Much of the science has yet to be developed examining how climate change affects ungulate migration and movement patterns, and how these changes may intersect with transmission lines and other human development. More research and evaluation are needed in these key areas:

- The impact of changing wildfire regimes and invasive species, specifically on big game migration habitat.
- The cumulative effects of concentrated anthropogenic development, specifically linear features, on movement rates, migratory use and demographic effects on big game populations and ecological connectivity overall, and whether there is a tipping point (or threshold) for maintaining populations in the face of these changes.[153]
- The synergistic and interacting impacts of climate change and anthropogenic development on predation and other ecological pressures on ungulate populations.
- Optimal configurations of transmission lines to minimize effects on site-specific ecological processes, as well as habitat use at various spatial scales.
- The impacts of human activities in GRSG habitat and how these affect population dynamics and sustainability, as well as population impacts from predation.

The inception of funding efforts such as the Department of Interior (DOI) Secretarial Order 3362[154] has allowed Western state and Tribal agencies to collect ungulate GPS-collar data

The inception of funding efforts such as the Department of Interior (DOI) Secretarial Order 3362 has allowed Western state and Tribal agencies to collect ungulate GPS-collar data at various frequencies.

A Free, Prior, and Informed Consent (FPIC) approach is critically important for legally required consultation and engagement with Indigenous Peoples and Tribal Nations.

at various frequencies. The collection of empirical data can assist with conservation and planning and enhance understanding of the effects of human development on wildlife. These projects have focused specifically on elk, mule deer and pronghorn across diverse areas to identify multiple ungulate migrations across the West. The U.S. Geological Survey (USGS) continues to work with partnering agencies and tribes to map ungulate migration into standardized documents.[155] By using ungulate GPS-collar data collected by state agencies and researchers, wildlife crossings have been sited in key corridors of animal movement and other new approaches to target mitigation for any linear feature (e.g., road, fence, railway) have been refined.[156]

Currently, specific relocation data on wildlife use and movements is not publicly available. Rather, empirical data is most likely shared on a case-by-case basis, with data sharing agreements created between collaborators. Data is typically managed in this manner because of its complex nature and concerns that incorrect inferences could be made that are not supported by the data itself. Researchers and decision makers must therefore work together to share and apply these data appropriately. Taking a more regional and standardized approach to data sharing agreements and data collection would be useful, as individuals and populations of wildlife use seasonal range and migratory routes that span man-made jurisdictional boundaries.

Across the Western U.S., ecological connectivity allows for functional and resilient landscapes, particularly those that cross jurisdictional boundaries. Assessing movement data for multiple species, including ungulates, will support scientists and resource managers in tailoring conservation actions[157] to maintain ecological connectivity and intactness (*See* Success Story 1). Indeed, ungulate movement data can also be used to identify priority areas for mitigation, even when movements cross jurisdictional boundaries and competing interests exist.[158] Still, state wildlife agencies could use empirically based landscape scale tools and mapping products, to effectively prioritize and manage wildlife populations within their jurisdictions.

Tribal Consent and Collaboration

Wildlife-responsible transmission development will require scientists, conservation organizations, grid advocates, hunters, anglers, and every member of the outdoors community to engage in transmission planning and siting processes. Collaboration and coordination with industry and state and federal decision makers is crucial. A **Free, Prior, and Informed Consent (FPIC)** approach is critically important for legally required consultation and engagement with Indigenous Peoples and Tribal Nations.[159] Federal agencies must meet their trust obligations and engage in government-to-government consultation when proposed projects will affect Tribes, their sovereign lands, and culturally significant species such as ungulates.[160] It is equally essential to create early, consistent, and meaningful collaboration with Environmental Justice communities. Historically, these nations and peoples have borne the burden of energy infrastructure development in the US, while receiving little to no benefits. We provide an example (See Success Story 3) where such needs are accounted for and uplifted.

Photo: Thainchai Sitthikongsa/Getty Images

A Decision Support Tool to Prioritize Conservation Efforts and Development Planning

We recommend the use of a dynamic decision-support tool (DST) that can help industry, state agencies, Tribes, communities, and others to avoid and minimize unintended impacts on multiple species and their habitat and identify optimal areas for conservation and development.

Why do we need a decision-support tool for the West?

Transmission infrastructure may exist on the landscape for decades, and the choices we make today may have consequences for wildlife years from now. Uncertainties around the impacts of climate change and land-use change on the Western landscape make it even more challenging to comprehend the likely effects of any given project on multiple species and the habitats that they depend on. In the face of such uncertainty, how can decision makers use data on historical conditions, anticipated climate impacts, and projected trends in land-use change to inform planning for conservation and development?

We recommend the creation and use of a **decision-support tool** (DST) to identify optimal areas for development and conservation. A tailored DST could support decision makers as they grapple with complex questions and considerable uncertainty. It can also be iteratively refined to incorporate new data and meet stakeholder needs. DSTs can aid the full spectrum of stakeholders in negotiating trade-offs, finding areas of agreement, and exploring alternatives.[161] In doing so, they can transform what may be an overwhelming volume of data into actionable information. Such tools come in many forms, but web-based applications that aid in visualizing dynamic data are innovative and powerful approaches to optimize conservation outcomes.[162]

A tailored DST could support decision makers as they grapple with complex questions and considerable uncertainty.

DSTs have proven to be invaluable in conservation planning in various contexts around the world.[163] DSTs have been developed to shed light on animal-vehicle collisions,[164] target beaver restoration efforts in appropriate areas (BRAT), reduce whale entanglement in fishing gear (NOAA), and identify optimal locations for development of carbon management projects in Wyoming (NWF). Such a tool, that also accounts for temporal changes, could be implemented immediately in the Intermountain West.

What would a DST need?

To help decision makers navigate the challenges of responsibly siting and developing transmission projects in the West, we recommend the use of a DST that can account for the following factors:

Photo: Tanner Saul/NWF

1. Species have differing requirements. It may be impossible to focus on all species, but ideally, the DST will offer the ability to compare the needs of multiple species – including migratory species with large, connected seasonal ranges.

2. Wildlife select habitats for a variety of reasons and at multiple scales.[165] A DST should support consideration of the impacts of infrastructure development on habitat quality and connectivity and ecosystem function, at the landscape level and at the site level.

3. Cumulative effects must be considered. Transmission infrastructure doesn't exist in isolation. Beyond the ROW, development of new transmission lines may entail the creation of new maintenance roads or substations, and it's likely to occur near areas where new renewable energy is being deployed. Siting should consider the locations of other existing (and, when possible, planned) infrastructure related to transportation, housing, or oil and gas development, as these developments can also act as barriers to migration and drive habitat loss.[166] Currently, at the federal level, evaluation of cumulative impacts of projects rarely extends beyond minimum legal requirements.

4. Climate change is altering habitat quality and sometimes eliminating habitat. Decision makers will benefit from being able to understand how climate change may make some portions of a species current range unusable – or make areas that are currently unusable more desirable. Visualizations of projected changes in precipitation, snowpack, or fire extent and severity could be overlaid onto current species' ranges.

5. Wildlife habitat often transects multiple jurisdictions and ownerships (and so do transmission lines). Decision makers will benefit from a better understanding of how transmission lines might intersect with habitat under various management regimes.

Putting the tool to use

A dynamic DST would combine empirical data on animal movement obtained from state wildlife agencies, researchers, and other sources with other relevant geospatial data to create species distribution and movement models. Data on current and projected climate impacts could be added, to understand potential changes in habitat suitability and connectivity over time.

To support broad usage, the DST could be an interactive web application. Users could toggle between various reference layers, such as protected area boundaries. They could also visualize data for annual habitat and habitat connectivity layers, for individual species or multiple species simultaneously, zooming in and out based on the agreed to scale by cooperators for the area of interest. Other results from a DST may indicate areas where multiple species' needs overlap, critical wildlife corridors, areas experiencing rapid change, and areas that are likely to be resilient to climate change (i.e., climate refugia). Finally, a DST could include layers on existing infrastructure (roads, buildings, and industrial sites) as well as planned or potential developments, including possible routes for a given transmission project.

The success of such a tool will require bringing together agencies and developers to use the best available data. Collecting more data on wildlife migration and seasonal habitats will make tool outputs more robust, and increase predictive certainty. Increasing the accessibility of data from agencies and researchers, with appropriate guardrails, should be a priority.

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A successful DST will be developed iteratively, to include new data, to accommodate user needs, to reflect new conditions, and in light of evaluations of its own success.[167] Data from monitoring of projects can inform decisions related to timing and placement of pending projects, provide a guide for regulatory oversight, and identify new monitoring needs. Both baseline data and post-project data on wildlife movement can serve as input for the decision support tool, further refining the tool and its outputs. This consistent feedback loop will help ensure the DST is effective and up-to-date, using an adaptive management framework. Over time, outputs from a DST could also be used to develop criteria that can be used by state, local, Tribal, and federal decision makers as they assess transmission siting and design.

In integrating and distilling an enormous amount of information, a DST could help transmission developers and other decision makers optimize selection of areas for conservation and development or identify critical gaps for management and planning – both now and in the decades to come.

Success Stories

Durable success in wildlife conservation and infrastructure development across the West can only be accomplished in partnership. This surely is the case when working with diverse stakeholders that may have varied and sometimes competing interests. The following stories highlight projects and partnerships that value united and diverse stakeholders to catalyze conservation success at a localized, project scale. These can help provide a proactive framework necessary for implementing responsibly planned and sited transmission projects in the Western US.

Success Story 1: Data-Driven Restoration and Mitigation Projects Promoting Wildlife Migrations and Habitat Use

Early integration of conservation considerations into transmission project development can reduce negative impacts. Here we provide an example from the Northern Sagebrush Steppe (NSS).

Key lessons learned:

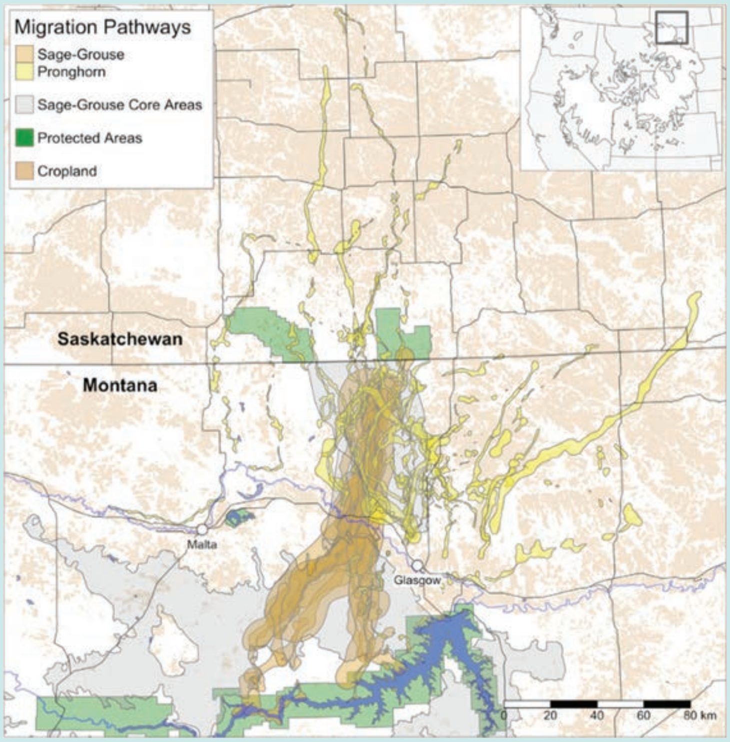
- Data-driven, targeted approaches to conserve wildlife needs can inform restoration projects.
- Sharing restoration project costs can be implemented by aligning NGOs, state and federal agencies, and developers.
- Simple fence modifications and the raising of existing bottom wires and lowering of top wires can reduce impacts to multiple species of wildlife, while continuing to function in keeping livestock in appropriate pastures.

Photo: Henrik Karlsson/Getty Images

The NSS is an international region across Southern Alberta and Saskatchewan, Canada and Northern Montana. In the U.S. this region consists of a mix of federal, state, provincial, and Tribal lands, although the majority of these lands are privately owned. Agricultural settlement across the NSS brought rapid and significant alterations to the land, including extensive cultivation, urban development, natural resource extraction, livestock grazing, fences, and transportation systems.[168] Land-stewardship practices by ranchers, balanced with habitat management by federal government, Tribal agencies, and NGO partners have allowed for a significant proportion of intact native grassland and sagebrush habitat to endure the pressures of habitat alterations. In turn, the region offers some of the best opportunities for multiple wildlife species conservation and their ability to complete annual lifecycle requirements.[169] Indeed, the longest recorded migratory movements made by both pronghorn and GRSG have been recorded across the NSS.[170] Even more revealing is the spatiotemporal overlap between GRSG and pronghorn migrations (See Figure 5).[171]

Equipped with empirical information, community-driven and collaborative organizations like the Ranchers Stewardship Alliance have implemented restoration projects using data-driven and targeted approaches to conserve wildlife needs. These organizations draw upon expertise from state and federal government, conservation organizations, and academic institutions. For example, researchers predicted migratory routes of ungulates, which helped the Alliance prioritize locations of restoration projects.[172] Restoration projects may include fence modification, reseeding native habitats, and installation of watering structures for livestock and wildlife. Funding for such projects came from cost-sharing efforts provided by multiple grants and federal programs, to make implementation dollars go farther.

Additionally, locally driven mitigation requirements for multiple wildlife offer insights to industry for mitigating future development and those most supported by local communities.[173] A long-term and incremental research project evaluating pronghorn in the Northern Great Plains determined appropriate fence modifications and specifications. These modifications are designed to assist in ungulate and upland bird daily and seasonal movements, while keeping livestock in appropriate pastures.[174]



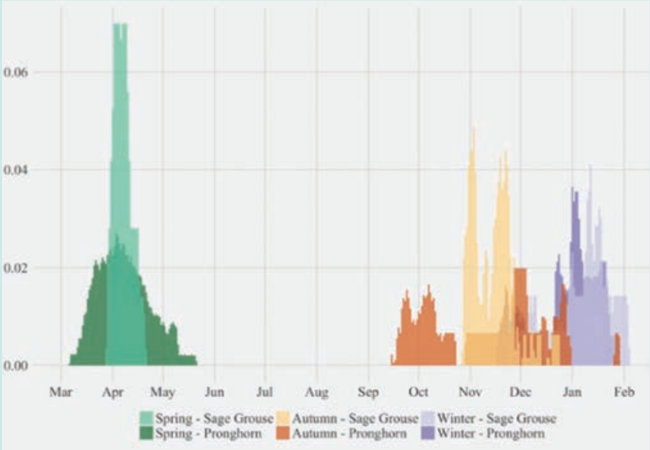


Figure 5. *The left-side image indicates spatial overlap between greater sage-grouse and pronghorn while migrating between seasonal ranges in North Central Montana and Southern Saskatchewan. The right-side image reveals temporal overlap while these two species migrate between seasonal ranges. Citation: J.D. Tack et al.,* Beyond protected areas: Private lands and public policy anchor intact pathways for multi-species wildlife migration *(2019).*

Success Story 2: Building Connectivity with Renewable Energy Development in Arizona

In 2019, the Arizona Game and Fish Department (AZGFD), county officials, a utility-scale solar development company, and private landowners created a "natural experiment." The experiment allowed the state to collect data on the effects of solar energy development and compare potential wildlife use through corridors of varying widths. For the project, AZGFD expanded their existing work and deployed GPS-collars on mule deer and pronghorn across parts of Northern Arizona, before 66 wind turbines and 17 different solar arrays were built. Financial support from 2018 DOI Secretarial Order 3362146[146] made this experiment possible.

Key lessons learned:

- Using GPS-collars on mule deer and pronghorn in the pre-construction phase of development for renewable infrastructure establishes an up-to-date baseline of these species' movement and migration patterns, which can inform later adaptive management and monitoring practices.

- Replacing the typically used, chain-link fencing for fencing with wider gaps or raising the bottom wire of a chain-link fence off the ground can provide access to habitat that otherwise would remain inaccessible for smaller species.

- Creating migration corridors of various widths that traverse the footprint of numerous projects concentrated in one area can help regulators test optimal corridor widths for migration.

- Newly deployed GPS-collars on pronghorn were helpful in using a "geofence" option that increases the frequency of collected locations from every 3 hours to every 15 minutes when individuals are near the development site.

Photo: Dennis Stogsidill/Getty Images

Northern Arizona consists of a patchwork of forested areas and grasslands, which includes a mix of private and public land ownership. GPS-collars helped the state identify important migrations made by mule deer and pronghorn as well as barriers to migration created by natural and anthropogenic features. Tracking mule deer and pronghorn with GPS-collars led the state to find that there was significant overlap between the proposed development and the habitats most used by mule deer and pronghorn for seasonal migrations (See Figure 6).

AZGFD collaborated with county officials, a utility-scale solar development company, and private landowners to create migration corridors of various widths that traverse the project site and the area where concentrated development would occur to test the optimal corridor width to permit pronghorn and mule deer migration. Together they decided to create migration corridors through the solar project site ranging in width from a few hundred feet to a half-mile wide. They created the migration corridors with fencing, which ended up splitting the solar projects into smaller areas that collectively still generated the same amount of electricity as the originally proposed projects.

They also deployed new GPS-collar technology that logs data every 15 minutes, when the pronghorn or mule deer are near the project site, which can be programmed into the collars by creating a virtual perimeter (commonly known as geofencing). This new technology is particularly informative, as previous iterations could only log information at a single pre-selected time interval. The geofence approach allows for maximizing battery life when animals are out of the range of the solar facility, while still collecting large-scale movements and allowing fine-scale, specific corridor use movements when they are near or within the facility.

Collaborative approaches to development, as in this case, help decision makers better understand the trade-offs associated with large-scale development to balance electrification needs of the power grid with the needs of wildlife.

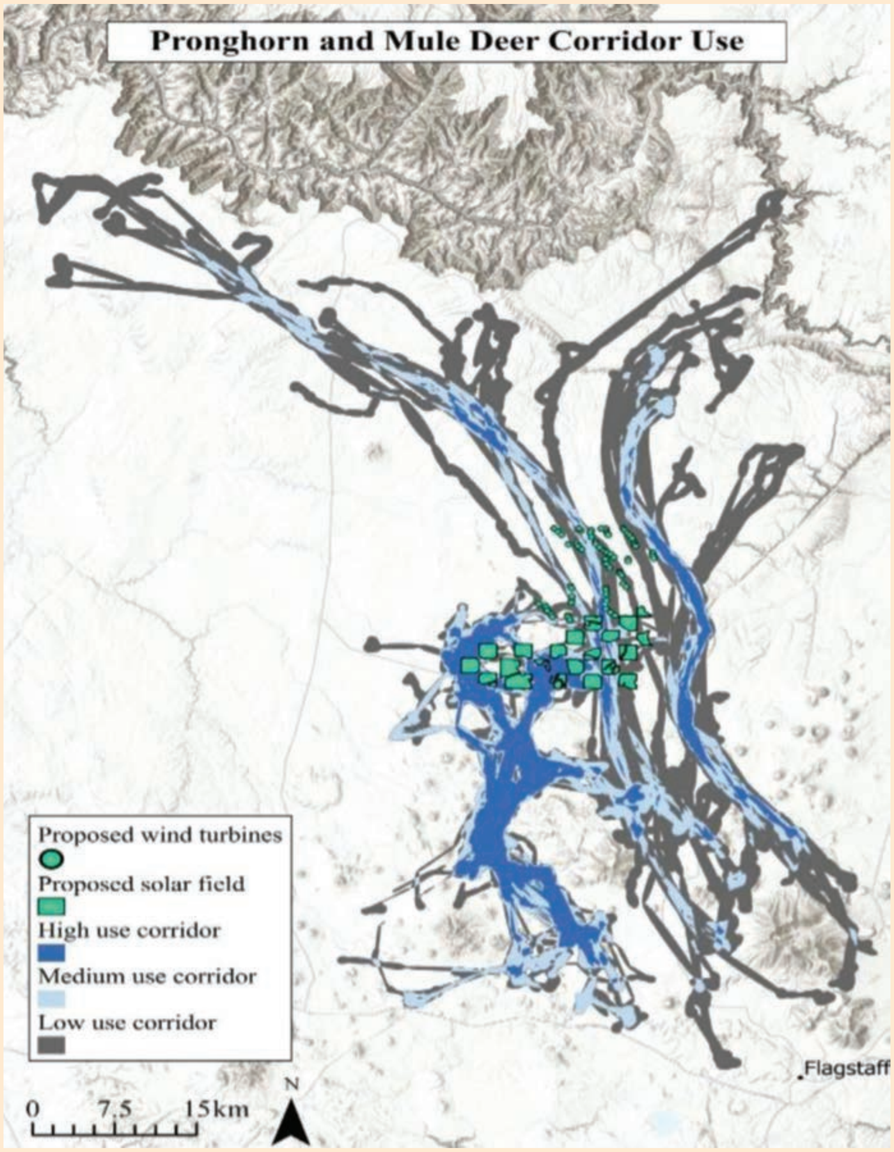


Figure 6. *Migration maps of the San Francisco Peaks mule deer herd and North of Interstate 40 pronghorn herd in relation to proposed wind turbine and solar development projects. Through partnership, corridors of varying widths allow for the continued movement of ungulates through the project site and allow the state to evaluate. Matthew Kauffman et al.,* Ungulate Migrations of the Western U.S. Volume 5 *(forthcoming).*

Success Story 3: The San Juan Interstate Wildlife Working Group

Mule deer and elk herds in the San Juan Mountains and surrounding landscapes of the Southwest US are somewhat unique in that their annual migrations can cross the jurisdiction of four separate government agencies, which each have the authority to manage and harvest animals independently. The four agencies charged with managing mule deer and elk are Colorado Parks and Wildlife, New Mexico Department of Game and Fish, Southern Ute Division of Wildlife Resources Management and Jicarilla Apache Game and Fish Department. Transboundary migrations were first documented through telemetry studies conducted by the Jicarilla Apache Game and Fish Department and soon after, interest from neighboring jurisdictions escalated. This shared interest and management responsibility prompted the four agencies to form the San Juan Interstate Wildlife Working Group (SJIWWG) in 1987, as a venue for sharing information and coordinating management activities. Since the early 2000's, the SJIWWG meets annually under a "good faith agreement" to discuss the results of their herd classification surveys, interstate movements and ongoing migration research, and hunting season and harvest plans for the upcoming year. Because these herds are potentially being harvested by multiple agencies, communicating each agency's knowledge of herd health and population trajectory is important and partner agencies have successfully adjusted hunt seasons and harvest quotas based on these meetings.

Challenges persist for big game herds that navigate across this cross-jurisdictional region, which include habitat conversion mainly from exurban growth and energy development, climate change impacts, disease, fragmentation from linear features along transportation corridors, and different visions from neighboring agencies on how the same herds should be managed.

Photo: Tanner Saul/NWF

Consistent communication and thoughtful discussion go a long way in avoiding surprises and misunderstanding regarding these herds. The San Juan Interstate Wildlife Working Group has been pursuing that goal for nearly four decades. Over the past two decades, all SJIWWG partners have actively been engaged in ungulate collaring efforts and sharing their results. For example, results from mule deer fitted with GPS collars have confirmed the need to work together on addressing current and imminent threats that migratory ungulate populations face (Figure 7). Additional results from Jicarilla Apache Nation elk (2014-2016)

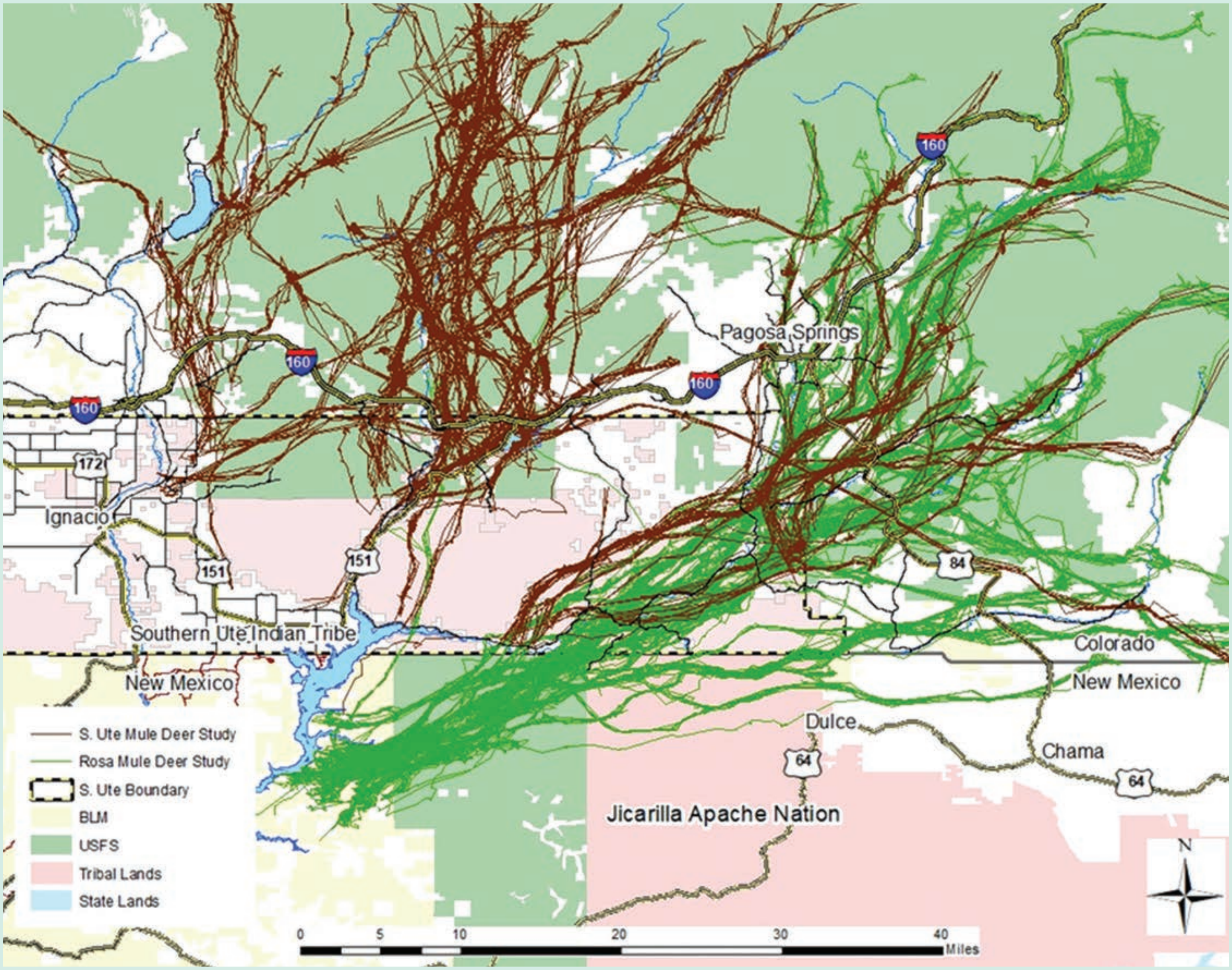


Figure 7. *Two studies reveal the transboundary requirements of mule deer populations across the region that include the Jicarilla Apache Nation, the Southern Ute Indian Tribe, New Mexico and Colorado. In addition to these jurisdictions, mule deer move across various landownerships that include federal, state, tribal and private lands. Each vector indicates an individual mule deer, with green vectors from the Rosa Mule Deer Study and brown vectors from the Southern Ute Mule Deer study. H. Sawyer et al.,* All routes are not created equal: An ungulate's choice of migration route can influence its survival *(2019).*

and mule deer (2017-2018) studies support the call for transboundary management by delineating elk and mule deer seasonal ranges (including core winter range and parturition areas), survival, and migration and stopover site identification.

Looking ahead, partnering agencies could provide cross-jurisdictional opportunities (e.g., coordination and leveraged funding) for habitat restoration initiatives, research projects and other specified management needs, to continue to find ways to compliment efforts for the benefit of migratory wildlife and sustainability of ecological connectivity across the region.

Photo: Harry Collins/Getty Images

Recommendations to Support Wildlife-Responsible Transmission Planning, Siting, & Development

As the power grid continues to be updated, these recommendations will help set the stage for effective collaboration to optimize siting and minimize impacts to wildlife.

To prevent unintended impacts to wildlife and communities, the National Wildlife Federation recommends first minimizing greenfield transmission development in undisturbed and natural areas, where possible. A growing body of evidence indicates that upgrading existing transmission infrastructure to increase capacity through grid-enhancing technologies and the use of advanced reconductoring in existing rights-of-way can help us meet needs – and do so cost effectively.[175] Transmission towers and additional infrastructure such as substations may also be sited on lands that have already been disturbed or degraded.

Where greenfield development is necessary, decision makers need high-quality and up-to-date information that considers a suite of factors. As summarized above, a dynamic decision support tool – and the adaptive wildlife management framework it informs – would be invaluable to transmission planning, siting, and development. It would help ensure that the Western grid of the future doesn't inadvertently undermine the conservation and management of migratory species. As a complement, the following recommendations synthesized from State Wildlife Action Plans, peer-reviewed literature, and conversations with experts are provided. As the power grid continues to be updated, these recommendations will help set the stage for effective collaboration to optimize siting and minimize impacts to wildlife. These recommendations serve as foundational steps towards balanced implementation efforts or to articulate meaningful policies and best available practices.

Photo: rpbirdman/Getty Images

Successful wildlife conservation and responsible transmission development depend on authentic public engagement. Public engagement depends upon opportunities for engagement, data and procedural transparency, and the cultivation of respect and trust, which can take time.

The following recommendations for state wildlife agencies and industry provide both short, mid-term, and long-term guidance to achieve balanced and achievable decision-making solutions.

Near-Term Recommendations (By 2030)

Implementation by: State Wildlife Agencies

- Learn more about anticipated transmission development and its intersection with existing, relevant wildlife research.
- Require energy development projects to complete pre-construction and post-construction monitoring as a permitting requirement. Incorporate research questions into these monitoring and construction design plans.
- Implement siting requirements such as avoidance of certain high-quality habitats and utilizing thresholds for size and density of project disturbances.
- Create siting requirements such as incentivizing use of already disturbed areas of land to limit greenfield development.
- Develop standard data management protocol for all taxa to improve inventory management.
- Standardize baseline data requirements and survey procedures for application on proposed energy projects to build state or regional databases that can be coupled with ongoing agency and academic research.
- Communicate with adjacent jurisdictions (e.g., states, Tribes) for effective multi-jurisdictional management.
- Identify sites of high quality habitat and conservation value to inform siting of energy development and promote habitat connectivity.
- Standardize the aerial flight framework used with GPS to track, inventory, and manage ungulate populations data.
- Use data from existing projects to inform wildlife management and mitigate impacts near planned transmission projects.
- **Begin building a multi-jurisdictional DST.**

Implementation by: Industry

- Develop relationships with state wildlife agencies and conservation advocates during project design and permitting stages.
- Fund and execute applied mitigation measures, such as fence modification and replacement.
- Allow publication of research and data from surveys and monitoring on proposed and constructed infrastructure projects.
- Work with researchers and agencies to design and implement exclusion fencing that meets the safety needs of the energy companies with mitigated impacts to wildlife.
- Use integrated pest management (IPM) to mitigate impacts related to the introduction or spread of invasive plant species as well as pests or pathogens.
- Support Recovering America's Wildlife Act, which can help state wildlife agencies receive the funding and capacity needed to achieve their recommendations listed here.
- Reconductor and increase the capacity of existing lines where possible.
- Offer research and monitoring projects during development phases to collect data for input into the decision making framework. Using more current data will offer industry more certainty.
- Learn about communities hosting potential projects, identify leaders, and establish and execute a transparent and robust engagement plan that responds to concerns and needs. If proposing a project on Tribal lands, adhere to FPIC (Free, Prior, and Informed Consent) principles.

Implementation by: State Wildlife Agencies and Industry

- Develop relationships with each other; especially important as many states are actively working on (or about to work on) updating state wildlife action plans (SWAPs). Develop requirements and guidelines for siting, construction, and monitoring of energy projects that can be utilized prior to project proposal/design.
- Complement Western science and data collection with Traditional Indigenous Knowledges. Learn how to keep Indigenous Knowledges confidential. This is particularly important as data is added into a decision support tool for widespread use.
- In some areas required transmission capacity can likely be met through co-location, reconductoring and strategically citing new transmission lines. Prioritize the reconductoring and co-location of existing transmission lines first, then develop new lines in greenfield areas chosen with state wildlife agencies and in consultation with SWAPs.
- Evaluate how existing management frameworks must evolve due to climate change.

Midterm Recommendations (By 2035)

Implementation by: State Wildlife Agencies

- Share wildlife data and collaborate with other state agencies in the region to evaluate baseline and monitoring data at the regional level. For example, effective wildlife management metrics are those related to demographic rates (births and deaths). Use tools such as remote cameras in concert with GPS-collars to track movements and habitat use before and after development to assess multi-scale use, potential impacts and, survivorship and recruitment of offspring.
- Evaluate thresholds to various development types, as well as additive impacts, by using simulation and scenario modeling and integrating with population modeling.
- When identifying priority areas or targeting approaches, use multi-species requirements. Multi-species requirements are those that consider the needs of a suite of species at multiple scales, not just one species in particular.
- Consider multiple scales in planning efforts – not only should the specific development site be considered but also its location in a broader-scale context. For example, target development in areas that provide ungulates adjacent wintering areas or migratory routes. If development is proposed in an isolated winter range, relative to overall distribution, that winter range would be more likely to have reduced use and offer lower safeguards, compared to winter ranges that were in nearer proximity. This would incrementally contract ungulate range over time.
- Reduce other stressors/pressures[176] – adaptive capacity to climate change can be increased by limiting other stressors, such as pollution and habitat degradation.
- Protect key migratory stopover sites, climate refugia, and wildlife corridors.[177]
- Collaborate and advocate for more funding for research institutions, like the climate adaptation science centers.
- **Refine a multi-jurisdictional DST via user feedback; incorporate additional data.**

Implementation by: State Wildlife Agencies and Industry

- Use an adaptive management framework to integrate new information as it is discovered. For example, research is conducted to assess threshold densities of linear features' impact on ungulate wintering ranges. Once these densities are known, stakeholders work to reduce the extent of linear features on identified winter ranges and use these results to effectively manage ungulates in other parts of their range.
- Track development phases (i.e., pre-construction, construction, post-construction monitoring) impacts on wildlife and habitats over time in a standardized fashion (e.g., GIS database) and make available to stakeholders for wildlife management efforts. In this manner, transparency is established for where and when development occurred.
- Prioritize net positive solutions to benefit climate and wildlife while achieving renewable energy goals.
- Create data-sharing frameworks; ensure data and insights are publicly available whenever possible, which will help improve transparency and spur further needed research. Frameworks should account for Indigenous Knowledges, and keep confidential where necessary.

Implementation by: Industry

- Continue to provide research and monitoring projects during development phases to collect data for input into the decision making framework. Using more current data will offer industry more certainty.

Long-Term Recommendations (By 2040)

Implementation by: State Wildlife Agencies

- Fully implement usage of a multi-jurisdictional DST; continue to refine and update the tool via stakeholder and user feedback and incorporation of new data.
- **Using the DST, map areas where development is least detrimental and identify important areas for big migration routes and ecological connectivity using multi-scale analyses, particularly regional spatial and temporal analysis.**

Implementation by: Industry

- Continue to offer transparent research and monitoring projects during development phases.

Conclusion

Conservation of the West's beloved wildlife enjoys robust public support – and in conserving the habitat of iconic migratory species, we can benefit other species and ecosystems. Migration reflects ecological connectivity. Although little research has explicitly examined the effects of transmission lines on movements and migrations of our focal species to date, there is no doubt that the habitat loss and fragmentation associated with transmission development could jeopardize conservation, in combination with the pervasive impacts of climate change. Still, the DST may provide greater decision-making certainty.

Photo: Tanner Saul/NWF

In an era of rapid global change, renewable energy generation and the associated transmission development present both a potential challenge, and an exciting opportunity to create a resilient power grid without exacerbating habitat loss and degradation.

To make the most of this opportunity, Western grid operators, decision makers, and wildlife experts must proactively plan energy transmission – both within and across regions. Where possible, additional capacity can be developed in disturbed areas and existing ROWs. Where new development is necessary, data can drive our decisions. By collecting baseline data and monitoring conditions after development, we can adaptively and iteratively improve management of existing projects and inform development of new projects. And when key stakeholders come together to collect and share data on wildlife movements, we can unlock the power of a dynamic, multi-species decision-support tool. With this tool, we can integrate explicit development and climate change scenarios with conservation objectives to maximize benefits for multiple species and avoid conflicts. As a result, developers, state and Tribal agencies, community members, and other stakeholders will be able to make informed decisions about transmission siting and build a grid fit for the future challenges ahead – without unknowingly undermining conservation goals.

Since transmission development is not separate from energy generation infrastructure, we must modernize how we assess the intersection of wildlife and development as we modernize the power grid. Just as energy transmission requires interregional interconnections to create a reliable and resilient grid, prudent wildlife management directs us to incorporate research, monitoring approaches and adaptive management to maintain and improve interregional wildlife habitat connections.

In an era of rapid global change, renewable energy generation and the associated transmission development present both a potential challenge, and an exciting opportunity to create a resilient power grid without exacerbating habitat loss and degradation.

Endnotes

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A Bison calf and its mother wander across the snowy meadows below the Grand Teton Mountains, near Jackson Hole, Wyoming. Photo: Annie Bailey

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1200 G Street, NW, Suite 900
Washington, D.C. 20005
www.nwf.org