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TECHNICAL NOTE

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Improving Fence Passage for Migratory Big Game

Examples and Lessons Learned from Wyoming's Migratory Big Game Partnership

Photo credits: Mark Gocke, Wyoming Game and Fish Department; Travis Zaffarano, University of Wyoming Migration Initiative (bottom right)

Purpose

Fences are a pervasive feature of western working landscapes and a useful management tool but they also have serious potential to impact wildlife, with some acting as movement barriers and others causing injury or even death. Fences are of particular concern for migratory populations of big game in the western United States, where herds often move hundreds of miles between seasonal ranges.

This technical note is intended for NRCS conservation planners and partners working with agricultural producers and public land managers to facilitate migratory big game movements. It draws upon the existing body of science and expertise of Wyoming partners engaged in this work for over a decade to share the best available information with others across the West.

The note supplements the NRCS National Planning Procedures Handbook, providing details throughout the conservation planning process on removing, modifying, or building fences when migratory big game is a resource concern. The note covers a variety of topics from inventory to monitoring, and presents design alternatives from avoiding fence impacts altogether to minimizing and mitigating impacts through 'wildlife-friendlier' fence options.

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Table of Contents

Photo: The Nature Conservancy

Introduction

Background

Fences are a pervasive feature of western working landscapes. They are used to manage or sequester resources, to prevent intermingling of wildlife and livestock, and to define property and political boundaries. In the 2014 Farm Bill alone, NRCS funded installation of over $290 million of fence; enough to circle the globe. The full impact of fences is difficult to calculate given that we lack data on fence locations, types, and designs. Comprehensive inventories are rare, and we currently do not possess fast and efficient techniques to inventory them (Buzzard et al. 2022). However, when detailed inventories are completed, the numbers illustrate the sheer scale of the issue; one study in Montana found over 21,000 miles of fence in two counties alone (Buzzard et al. 2022).

Landscape connectivity–defined as the degree to which a landscape facilitates or impedes movement among resource patches (Taylor et al 1993)–is a key element of wildlife habitat, particularly in the West where many species make seasonal movements across the landscape to fulfill their life history requirements. According to the NRCS fence conservation practice standard (CPS 382), fences are defined as "a constructed barrier to animals or people" with a stated purpose of controlling "the movement of animals, people, and vehicles…" Therefore, by definition, fences may decrease landscape connectivity for some species. While the term 'wildlife-friendly' is often used to describe improved fence designs that consider some wildlife needs, it should be noted that fences are rarely friendly to all species during all seasons. At best, a fence is semi-permeable and allows wildlife to pass with a limited risk of death, injury or stress. Simply put, fences are a management tool. They have positive impacts on some resources and negative impacts on others.

The American West is home to world-class populations of big game mammals, such as mule deer, pronghorn, and elk, that are culturally, economically, and ecologically important to the region. Over the past two decades, breakthroughs in technology (e.g., GPS tracking) have allowed scientists and state wildlife managers to better document and understand big game movements and migratory corridors (Berger

and Cain 2014, Middleton et al. 2020, Kauffman et al. 2020, 2022a, 2022b). Studies have revealed nuances between the different types of movements that occur as part of migration (Jakes et al. 2018a), migration pathways (Sawyer et al. 2009), and habitat use and selection during migration stopovers (Sawyer and Kauffman 2011, Sawyer et al. 2013). This research has led to a heightened awareness of the importance of maintaining landscape connectivity to sustain the region's migratory big game populations and factors that impair movements, including fences.

While fences themselves are relatively simple, their effects on big game are complex and difficult to determine. Where data are now emerging, the effects appear to be substantial. In the most extreme cases, fences can lead to injury or death of migrating animals that become entangled. However, most interactions with fences do not result in injury or death. Instead, they result in complex behavioral responses that incur a cost requiring wildlife to use energy they may need to survive the winter or prepare for fawning in the spring.

One recent study showed that mule deer and pronghorn in migratory herds of western Wyoming encounter fences more than 125 and 250 times per year, respectively, with 40% of these encounters resulting in altered movements - including bouncing away from fences, tracing along fences, and wandering back and forth along fences for long periods (Xu et al. 2021). Another study showed that repeatedly crawling beneath fences scrapes hair from the backs

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Photo: Greg Nickerson, Wyoming Migration Initiative, University of Wyoming

of pronghorn and is likely to contribute to increased thermal stress for the pronghorn (Jones 2014).

It is challenging to connect these adverse behavioral and physical interactions with fences to individual survival, overall population performance, or the long-term persistence of migrations. Yet several recent studies conducted in Wyoming's Sublette mule deer herd, which makes the species' longest known migration, suggest major impacts. One study showed that the survival of females in the herd is negatively associated with fence density in their home ranges (Xu et al. 2023). Another study found long distance migrants cross 171 fences annually on average (Sawyer et al. 2016). This growing body of work suggests that the effects of fences on migratory big game can be substantial but additional research is needed to understand the full extent.

As awareness of fence effects on wildlife grows among land and wildlife managers, landowners, and conservation partners, there is rapidly growing interest in how to reduce impacts. Yet, solutions can be complex. Most western landscapes include multiple co-occurring big game species, and these different species can have different capabilities for crossing fences and behave differently when crossing (Scott 1992, Karhu and Anderson 2006, Burkholder et al. 2018, Jones et al. 2018b, Jones et al. 2020, Segar and Keane 2020). Further, there are numerous fence designs to be considered (Scott 1992, Harrington and Conover 2006, Karhu and Anderson 2006, Jakes et al. 2018a, Jakes et al. 2018b, Segar and Keane 2020). Some fences are negotiable by some species, while others create complete barriers (Jakes et al. 2018b). Since fence modification and installation can be costly and this infrastructure may not be altered for decades, it is important that conservationists have the best available information to help landowners and managers make difficult decisions.

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This technical note draws upon the existing body of science and expertise of conservation practitioners in Wyoming to help other NRCS conservation planners and partners better understand the ecology of big game and fence interactions and use that to facilitate big game movements across working landscapes. The note is organized around the NRCS conservation planning process and provides details on removing, modifying, or building fences when big game movement is a concern. The note covers a variety of topics from inventory to monitoring, and presents design alternatives from avoiding fence impacts altogether to minimizing and mitigating impacts through 'wildlife-friendlier' fence options.

Wyoming's Migratory Big Game Partnership

The Wyoming Game and Fish Department and many conservation partners have been working together for decades to study and protect important seasonal habitats and migratory pathways for big game–including some of the **longest migrations ever recorded**. In recent years, the University of Wyoming's **Wyoming Migration Initiative** has played a leading role, bringing together scientists and wildlife managers to advance the understanding, appreciation, and conservation of migratory ungulates by conducting innovative research and public outreach. In northwest Wyoming, research and mapping efforts have shown that elk, mule deer, pronghorn, bighorn sheep, moose, and bison migrations are integral to the Greater Yellowstone Ecosystem, a globally significant landscape which encompasses extensive working lands (Middleton et al. 2018, 2020).

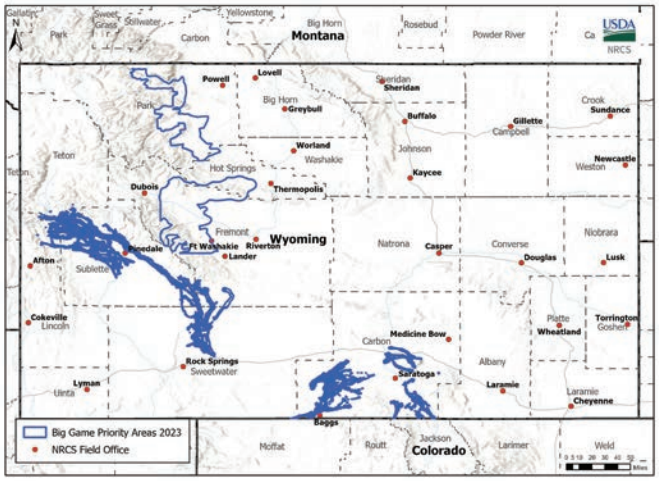


Figure 1: Wyoming Big Game Conservation Partnership priority area map for targeted Farm Bill delivery to conserve big game migrations on working lands.

The state of Wyoming's **Migration Corridor Executive Order** has facilitated a variety of proactive measures to conserve big game migrations including policy protections for designated corridors, prioritization of wildlife overpasses and road crossings, and the expansion of conservation easements, habitat improvements, and fence modifications. Since 2018, the Department of Interior's **Secretarial Order 3362** has brought resources to increase both research and habitat improvement in state-identified priority areas for migratory big game. In 2022, USDA piloted a Migratory **Big Game Conservation Partnership** with the state of Wyoming to scale-up voluntary efforts on private working lands to conserve migratory big game populations (Fig. 1). In 2023, USDA announced expansion of the Wyoming pilot to include Idaho and Montana, and committed to development of a **Working Lands for Wildlife** Framework for Conservation Action for migratory big game across the western U.S. All of these policy and management efforts seek to balance the needs of migratory big game with the economic viability of working lands. As a result, NRCS conservation planners increasingly require the best available science and management practices to inform effective conservation delivery to improve big game migrations.

The Big Game Conservation Partnership seeks to enhance and replicate ongoing successes to achieve measurable outcomes for big game. Community-based efforts, such as the **Upper Green Fence Initiative** and **Absaroka Fence Initiative**, demonstrate how local NRCS, Wyoming Game and Fish Department, Conservation Districts, and many other partners are already working collaboratively to hone best practices and achieve results at landscape scales in some of the most important migration pathways in the country, providing examples and lessons learned for others to consider before getting started (Box 1).

Since fencing is among the top practices used to facilitate grazing management in big game habitats, Wyoming NRCS has worked closely with the Wyoming Game and Fish Department and other State Technical Committee partners to formally adopt a wildlife-friendly fence position. The NRCS national fence practice standard (CPS 382) sets a minimum criteria that planners "design, locate, and install fences to minimize impacts on local wildlife as appropriate." However, states may exceed this standard to incorporate more stringent requirements when necessary. Wyoming's wildlife-friendly fence position means NRCS may only recommend approved fence types that adhere to the best available science to be considered wildlife friendly. In addition, Wyoming NRCS no longer provides financial assistance for woven wire fences or other unfriendly fence designs (with limited exceptions) because of the well-documented hazards posed to wildlife. Through its proactive leadership on this issue, Wyoming NRCS and partners have provided a model for how other states can take an integrated approach of policy changes and improved conservation planning and practice design to benefit big game.

Wyoming NRCS has worked closely with the Wyoming Game and Fish Department and other State Technical Committee partners to formally adopt a wildlife-friendly fence position.

Box 1. Summary of Lessons Learned from Wyoming's Wildlife-Friendly Fence Initiatives

- Develop a shared vision and understanding with local partners. This includes desired outcomes, where to prioritize work, how to respond to landowner interest or requests, roles and responsibilities of each team member, etc.
- Be flexible and patient. Collaboratives/partnerships often evolve and change over time in people, responsibilities, and process.
- For partnerships to work, everyone has to 'give' to 'get'. Individual members need to be selfless and learn to leverage resources of the partnership (both technical and financial) to benefit the overall goals of the project.
- Consider other solutions. Keep an open and creative mind, and listen to the needs of landowners. Our understanding of the issue is evolving and innovations continue to emerge, so adaptive management and thinking is critical to being effective.
- Monitor and document efforts and outcomes as much as you can to help tell the story.
- Involve the local stakeholders, conservation districts, and other agency representatives early in the process.
- Ensure the human capacity is in place to deliver. To successfully scale up, partnerships must do more than just generate interest. Make sure the staffing is adequate to complete the entire conservation planning process.
- Always be thinking of ways to reduce the number of fences on the landscape or strategically place crossing structures.
- Align statewide policy and standards to support wildlife-friendly landscapes and fence designs. Local conservation efforts must be supported by state level policies and practice standards that encourage and incentivize innovation and adoption of wildlife-friendly practices.
- Understand what the resource concerns are and determine if we know how to fix them. Balancing big game and livestock needs can be challenging. In some instances, you may need to pilot new ideas or techniques before addressing the resource concerns at a broader scale.
- Keep the desired outcomes in mind. Success is not determined by money spent, acres treated, or contracts written. Rather, true success is about increasing voluntary conservation adoption to achieve outcomes that benefit producers, working lands, and wildlife.

Big Game & Fence Interactions

Recent research has raised awareness of the vast scale of fencing in global rangelands and its potential impacts on key migrations. For instance, in Kenya's Mara ecosystem, changing land use practices have led to a 740% increase in fenced land (Løvschal et al. 2022), with major impacts on migratory wildebeest populations that may bode the partial collapse of this ecosystem (Løvschal et al. 2017). In the Greater Yellowstone Ecosystem, one study conservatively estimated nearly 10,000 miles of fences in the winter ranges of migratory elk herds alone (Gigliotti et al. 2022), and another drew on agency records to map more than 4,500 miles of fences (Xu et al. 2023).

Despite growing awareness of the prevalence of fences and their potential impacts, the ecology of big game and fence interactions remains relatively understudied, and major knowledge gaps remain, with most recommendations for wildlife-friendly improvements coming from local field trials, observations, and experience (Jakes et al. 2018b). Knowledge of broad-scale effects of fences on wildlife populations and ecosystems remains unknown. Impacts of fences on big game are often observed and discussed at the scale of individual animals or herds, such as mortalities or barriers, making it easier to dismiss the cumulative effects on whole populations.

Big game and fence interactions can be direct (physical) or indirect (behavioral), changing how animals utilize the landscape and access food, water, and cover (Jakes et al. 2018b). Direct effects include mortality, injury, and hair loss as a result of animals contacting fences and are the most readily observed consequences of fences. Indirect effects are more subtle and include things like pacing up and down fences, dehydration, and overall stress. Although most fence interactions are negative, some positive effects can come from fences designed to protect big game from harm, such as roads, especially when combined with dedicated wildlife crossings that allow for safe passage.

While the variety of fence designs is vast, we know that certain fence types pose particular problems and that those problems may vary by species. In addition to fence types, there are particular design features that can increase aversion to crossing a fence. Several examples include woven wire fences, taller fences, fences that pose visual barriers, and buck-and-pole fences.

Woven wire fence is an effective barrier that requires animals to be able to jump. For juvenile animals, this is often not possible. Pronghorn have such a strong preference for crossing under a fence that they are unlikely to cross even though they are physically capable of jumping the fence. Increased fence height reduces crossings in nearly all cases. This becomes even more problematic when the fence is placed on the contour of a slope, where the topography increases the effective height of the fence.

Below is a summary of species-specific interactions and key features of fences that seem to be most important to facilitating movements based on our current understanding of the ecology of big game and fence interactions. It is anticipated these insights will continue to change as additional research sheds light on the multi-scale effects of fences on big game.

Mule deer

Photo: Mark Gocke, Wyoming Game and Fish Department

Mule deer most often jump over fences. However, they do exhibit behavioral flexibility when crossing fences, both jumping over and crawling under fences. The ability to crawl under fences is particularly important for fawns. While more flexible in their crossing behavior than some species, there are still particular fence types that pose a problem for mule deer. These include woven wire, buck-and-pole, and fences that are either too tall or have poorly-spaced wires.

Pronghorn

Although they are capable of leaping over a fence, pronghorn typically prefer to crawl under. This makes some types of fence problematic for pronghorn, including fences with low bottom wires, woven wire, and buck-and-pole fence. Snow accumulation in winter can compound these challenges.

Photo: Mark Gocke, Wyoming Game and Fish Department

Elk

While elk are capable of clearing most standard fences, certain designs and fence visibility can be problematic. First, elk calves and yearlings have difficulty jumping over a fence. So, woven wire and fences with low bottom wires are problematic. Buck-and-pole fences pose difficulties because of the 3-dimensional nature of the design. Experience in Wyoming has shown that pole-top fence improves visibility for elk, but when it's used in short sections, elk just move along the fence to cross where there are only sections of wire. Additionally, the highly social nature of elk and their large body size pose fence maintenance problems for landowners. Crowding and pressure to cross as well as the sheer number of animals crossing can cause a great deal of damage. A lower top wire, let-down fence, or adjustable wire fence in high traffic areas may be needed to facilitate movement and reduce damage to fences.

Photo: John Carr, johncarroutdoors.com

Bighorn Sheep

Most fence literature discussing bighorn sheep relates to 'quarantine fence,' where the vulnerability of bighorn sheep to livestock disease is a concern. Work with the state wildlife agency prior to modifying fences to ensure that increased passage does not pose a threat to the typically small and isolated bighorn sheep populations.

When promoting passage for bighorn sheep, current thought is to use the same design requirements as mule deer.

Moose

Although they are capable of crossing most common fences, moose have difficulty with buck-and-pole fences, woven wire fences, fences with low bottom wires, and fences with poor visibility. In addition, moose calves have difficulty with fences when they are first born, so opening gates during the spring is encouraged. Moose often use habitats with a lot of browse, which typically means there will be poor visibility for fences. Moose also have very poor eyesight, exacerbating the fact that dense vegetation obscures fence visibility.

Adding markers to fences in strategic locations helps reduce collision risks. Photos: Jeremy Roberts

Co-occurring species: Sage grouse

Sage grouse are another species of high conservation concern co-occuring in big game habitat that are known to experience negative impacts from fences. Direct mortality can occur from bird collisions with fence wires. Sage grouse often fly low to the ground, just above shrubs, in low light conditions in the early morning or late evening hours during which fence wires may be difficult to detect. Bird strikes with fence wires have been especially noted in breeding habitats near leks and in winter concentration areas. Terrain ruggedness and proximity to leks are two primary factors associated with fence collision risk across the landscape (Stevens et al. 2012a). Increasing fence visibility can help mitigate impacts of fences on sage grouse. The strategic addition of vinyl markers affixed to fence wires has been shown to greatly reduce collisions over unmarked fences (Stevens et al. 2012b), but this has not been extensively studied and some anecdotal evidence from Wyoming indicates certain fences with high densities of sage grouse nearby continue to pose a hazard for strikes. Spatial planning tools have been developed to help identify areas of potential high risk on the landscape (Stevens et al. 2013).

Conservation Planning to Facilitate Big Game Migrations

Conservation Planning at Area-wide and Ranch Scales

The NRCS Conservation Planning Process provides a useful framework for conservation planners to help producers reduce harmful big game and fence interactions and facilitate animal movements across the landscape (Fig. 2; NRCS 2021a). Regardless of the spatial scale of planning, from an individual ranch to a whole watershed, following this process will help conservationists more effectively achieve desired outcomes of planned practices. Therefore, the remainder of this technical note is organized around the three phases of the Conservation Planning Process: Phase 1: Collection & Analysis (Inventory), Phase 2: Decision Support (Design), Phase 3: Application & Evaluation (Implementation).

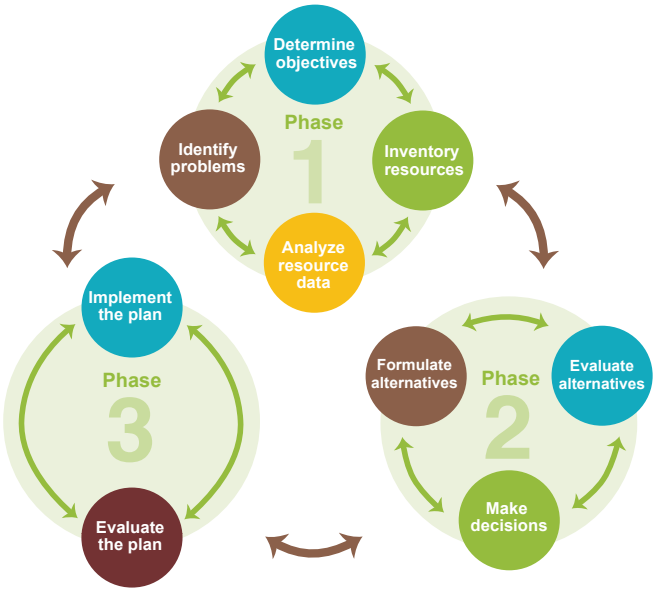


Figure 2: NRCS Conservation Planning Process

While it is beneficial for any willing producer to do their part to facilitate big game passage, achieving population-level outcomes for migratory big game typically requires a coordinated, area-wide planning approach given their vast movements across multiple land ownerships. Prior to opportunistic ranch-scale improvements, planners should 'zoom out' and consider how their county or work area fits into the regional or statewide picture. Maximum biological outcomes for big game occur when conservation actions are strategically targeted in high-priority landscapes, within specific movement pathways, and where there is the cultural will and readiness to take action (NRCS 2021b; Fig. 3).

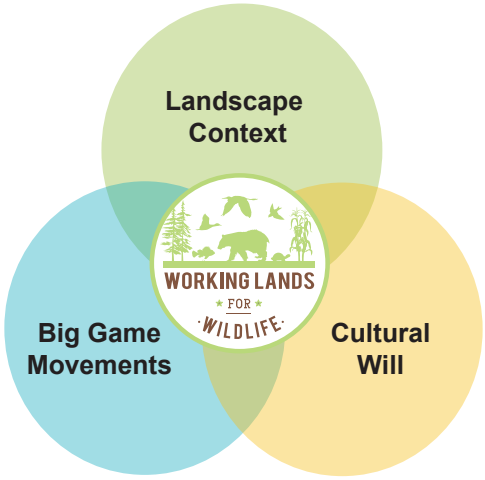


Figure 3. Combining information and data on landscape context, big game movements, and cultural will helps planners maximize outcomes. Graphic from Working Lands for Wildlife (NRCS 2021)

Many western state wildlife agencies have identified priority big game herds and management units where multi-faceted practices are being implemented to improve landscape connectivity and population performance. Tribes are also important partners and sources of Traditional Ecological Knowledge (TEK) regarding big game migrations. Incorporating local data and knowledge about specific big game movement corridors or areas of heavy seasonal use can further amplify benefits of individual practices. Prioritizing conservation planning in these landscapes, and specific locations within landscapes, increases the likelihood that local management actions to improve fence passage will lead to the broader outcome of healthier big game populations. Perhaps the single most important factor in determining success at the landscape scale is working in areas where producers, federal and state land managers, and other community-based partners are ready to collaborate and act across boundaries.

Achieving Better Outcomes Through Partnerships

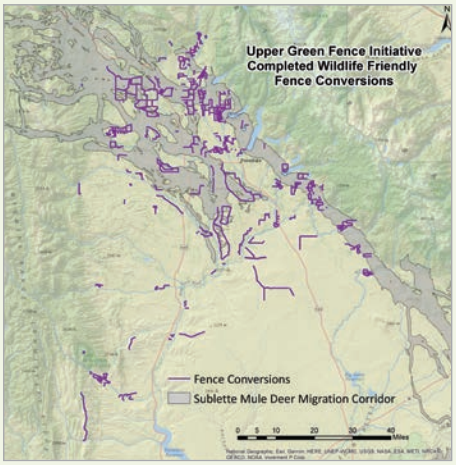
Collaboration and partnerships are essential in achieving success in landscape-scale conservation outcomes. This is particularly true for addressing wildlife resource concerns in the western U.S. where animals often utilize multiple landownerships, such as private, federal, state, and tribal lands, to meet their seasonal habitat needs. As a result, there are complex ecological and social networks, diverse land uses, competing demand for resources, and many other factors that need to be considered. Establishing a shared vision early on with community-based partners of achieving wildlife conservation through sustainable agriculture is essential to scaling up across working landscapes (NRCS 2021b).

Successful conservation initiatives require a collective effort of various individuals and organizations with different skill sets and resources to achieve a common goal. Stakeholders can pool expertise, resources, and knowledge to create effective strategies and effective implementation. Partnerships help to leverage funding and attract support across sectors, including government agencies, private landowners and entities, and communities. These efforts foster exchange of knowledge, learning, and best practices, which aids in improved outcomes. Collaboratives and partnerships have a higher chance of success than efforts that operate in isolation. Where migratory big game is a priority resource concern among producers and stakeholders, NRCS planners are highly encouraged to enlist conservation partners in an area-wide planning approach to achieve the best possible outcomes. Box 2 highlights an example of what is possible through community-based collaboration from the Upper Green River Basin of Wyoming.

While taking an area-wide approach is ideal, proper pacing is also essential for building trust and support for adopting new practices. Some communities may not be fully ready and willing to change traditional livestock management approaches and fencing designs. In these cases, working with respected leaders and early adopters in the community is a powerful approach to demonstrating practice benefits and considerations to neighbors and garnering additional interest among other producers to participate.

Box 2. Partnerships in Action: Wyoming's Upper Green Fence Initiative

Conservation partners in Sublette County, Wyoming, have a rich history of collaborating to achieve landscape-scale outcomes across ownership boundaries. The Upper Green River basin, centered around Sublette County, is renowned for its big game migrations and abundant sage grouse populations. One of the threats impacting migratory ungulates and sage grouse in the region is fencing that restricts crucial movements, poses risks of entanglement or collisions, and results in animal injury and mortality. Since 2012, a coalition of partners from the Wyoming Game and Fish Department, NRCS, Sublette County Conservation District, The Nature Conservancy, Green River Valley Program of the Jackson Hole Land Trust, Bureau of Land Management, private landowners, and other agencies and non-governmental organizations have worked collaboratively to make nearly 700 miles of fence wildlife-friendly in high-priority locations. Fence improvements include converting old fences to newer wildlife-friendly designs, removal of unnecessary or harmful fences, and making simple modifications to existing fences to facilitate movements in crucial habitats.



Known as the Upper Green Fence Initiative, the effort leverages each partner's unique resources, landowner relationships, and capacities to improve problematic fences in strategic locations. Various partners contribute local knowledge and expertise, wildlife data, fundraising and grant writing, field staff and labor, and project implementation funding. For example, partners such as the Wyoming Game and Fish Department, Sublette County Conservation District, NRCS, and others work together closely to provide data and expertise on wildlife corridors and wildlife-friendly fence designs, secure and administer grants to help inventory fences, and help landowners design and fund necessary fence conversions or modifications. To improve efficiency and outcomes, the Initiative developed a prioritization tool to better communicate to partners, producers, and contributors when and where resources will be allocated first (Appendix 1). The Initiative has been instrumental at implementing this program at a landscape level and increasing public awareness of the risks fences can pose to wildlife. The partnership attributes its success to 1) the dedication and motivation of the individuals on the team, 2) the unique roles they play in providing the necessary technical expertise and funding for project planning and implementation, and 3) their respect and trust with one another to address a common vision of healthy working landscapes in an area of great importance to migrating big game and sage grouse.

Phase 1: Inventory

Conservation planning begins with the inventory phase to gain a better understanding of the local ecology of the site and surrounding landscape and identify potential problems and opportunities. Simple land management decisions can have cascading positive and negative effects on soils, plants, and animals, so this planning phase is essential for establishing a baseline assessment of producer objectives, natural resources, and existing management infrastructure. This inventory can be used at the field level for ranch-scale planning or aggregated up to area-wide planning effort. Three primary elements of this planning phase related to improving big game passage include: 1) assessing big game ecology and habitat use, 2) inventorying existing fence infrastructure, and 3) combining big game and fence data to assess potential risks.

Evaluating Big Game Seasonal Habitat Use

The importance of thinking at multiple spatial scales is critical when managing ecological processes (Wiens 1989). This is especially true when dealing with ecological phenomena like big game migrations that occur over hundreds of miles and millions of acres. A broad partnership of state and federal wildlife scientists has mapped migration routes for over 150 populations of mule deer, elk, pronghorn, moose, bison, and white-tailed deer in the western U.S. (Fig. 4; see: **https://westernmigrations.net/**). This data provides a helpful starting point for area-wide planning related to some of the best documented big game migrations.

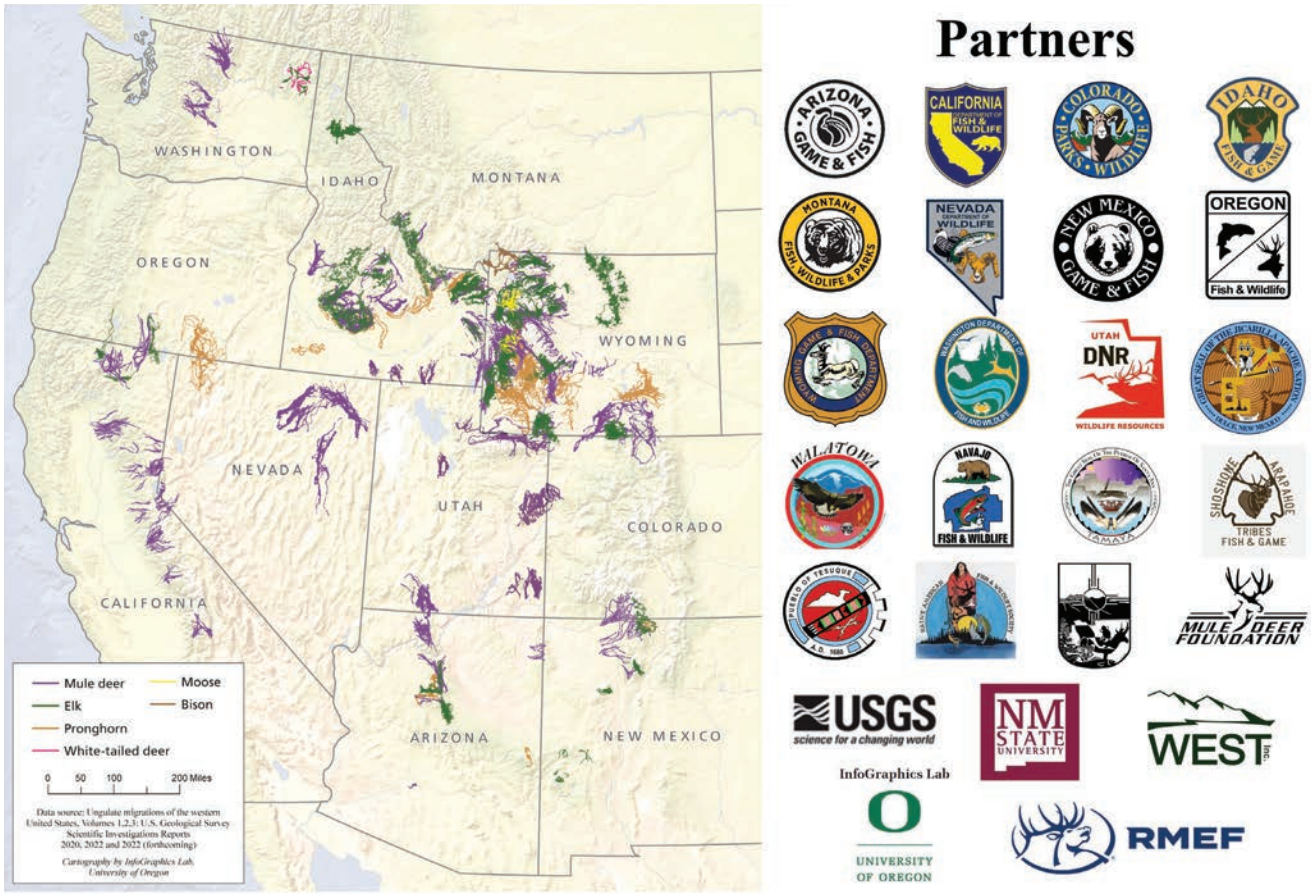


Figure 4: Mapped and published big game migration routes in the contiguous western states, as of April 2023. These maps are a good source of information to support areawide planning. Map provided by USGS and their big game partnership.

To maximize benefits for big game passage, planners need to be asking questions from broad, landscape scales all the way down to individual ranches and fences. While it is possible to identify priority fences for modification on any ranch, taking an area-wide planning approach will help planners focus limited conservation funding on the highest priorities. Ideally, planning would start with answering questions at broad, landscape scales, then local questions at the level of an individual ranch and, ultimately, end with addressing questions about specific fences for removal or modification. Below are some key questions planners should ask related to these different scales:

Area-wide Questions

1) What are the state's priority areas for big game migration and passage?

Where migration routes have been mapped, use the maps to identify where to focus work and to guide ranking for delivery of program financial assistance, otherwise work with the NRCS state/area biologist and state wildlife agency representatives to prioritize areas for focused work.

2) Which big game species are of concern in the county or service area?

Turn to the NRCS state/area biologists and state wildlife agency representatives to identify the big game species of interest in the area.

3) Which habitats are big game species of concern likely to be found in and when?

Ask the NRCS state/area biologist, partner biologists, or state wildlife agency which habitats are more important for the species of interest and when they typically use those habitats.

4) Has an area-wide assessment been done on the extent, location, and condition of fences?

If not, consider initiating an area-wide fence assessment in high-priority habitat areas while providing one-on-one assistance to individual producers. This will aid in targeting future efforts and investments.

Ranch-scale Questions

1) Do you have a map of all your fences?

If not, consider assisting the producer with a ranch-level fence inventory.

2) Which areas are the big game species using? Are there known problem areas?

Ask the landowner where they tend to see the big game on their ranch.

Ask if they have areas with consistent fence damage, or where they can see that animals may be crossing over or under the fence.

3) What time of year are they using the area?

Ask the landowner or local experts when they tend to see most of the species of concern.

4) Which habitats are the big game species using?

Ask the NRCS state/area biologist or state wildlife agency representatives what habitats are heavily used during migration for stopover and feeding.

Species-and Fence-specific Questions

1) What life stages are the most critical for the species of interest?

Identify the big game species of concern and whether the concern is only with adults or if fawns/calves/yearlings require attention.

2) Is the location of the fence posing additional problems?

Is the fence located on a slope where an animal coming up the hill will perceive it as more of a barrier?

Consider fence visibility.

i. Is it in a heavily vegetated area where it will be relatively obscured?

ii. Is it visible to the species of concern? (e.g., poor-sighted moose or sage grouse that might be flying at the height of the top wire)

Fence Inventory

Fences typically fall into four categories: livestock, exclusion, boundary, and conservation fences (Jakes et al. 2018b). Fences are often planned and implemented to facilitate grazing management typically associated with attempting to achieve better livestock distribution. Understanding how the landowner uses the fences for livestock management will be essential and will help the planner and landowner assess the fence risk and balance the needs of management.

In addition to assessing rangelands for plants, soils, water, wildlife and livestock resource concerns, recording existing infrastructure is critical when completing a baseline inventory (Table 1). For existing fence infrastructure this can include mapping locations, existing as-built specifications, natural barriers, water locations for livestock and wildlife, and utilization levels and patterns by livestock and wildlife.

The first step in inventorying fences is to georeference and attribute the existing pastures, fence locations, fence type, and existing conditions. A variety of survey tools or documents can be used to record this information. Wyoming NRCS and partners are testing a mobile fence survey app that allows users to collect important and consistent information that can be used and shared with the landowner and partners for planning purposes. The Wyoming NRCS Fence Job Sheet is used to certify newly installed fences, and this 'as-built' documentation can be an easy form for documenting existing fence conditions (NRCS 2022). Utilize maps to identify corridors, habitats, watering features, etc. Photographs are useful for documenting existing conditions.

Fence Risk Assessment

Combine big game and fence inventory information to assess relative risks, needs, and feasibility at the area-wide and ranch scales. Below are some simple steps to help identify potential risks and prioritize where to focus fence passage improvements.

Area-wide Risk Assessment

1) Map out areas within the county or service area where fences might be a problematic or a priority to address for each species of concern.

2) Consider engaging local producers and partners in these locations in a coordinated, area-wide planning effort to address big game fence passage issues across ownership boundaries.

3) Once a coordinated plan is in place, move to ranch-scale outreach and planning with willing producers in these targeted geographies.

Ranch-scale risk assessment

1) Using a fence inventory map, migration data, and local knowledge about big game habitat use, highlight fence sections that may be problematic or of concern. Note primary seasons of big game and fence interaction where appropriate.

2) Working with the landowner, identify any fence sections that are not needed and no longer required to meet their management objectives and sections may be candidates for removal.

3) If the landowner is willing to consider addressing big game and fence resource concerns, move to the next phase of the planning process to identify acceptable alternatives and designs. Remember that there may be some smaller sections of fence that are left in current form for livestock management objectives, but weigh risks, implications and alternatives to wildlife.

Table 1. Key Elements to Capture During Inventory of Existing Fences	
Location	Capturing accurate location allows for the planner to attribute fence stretches by multiple categories. This assists with area-wide planning, prioritization of funding, and allows the planner to utilize larger-scale migration maps to understand the existing demand and barriers that could exist.
Fence Type	Note fence type and details related to wildlife use or existing wildlife-friendlier modification features. For example, is the fence a wire fence, with or without a pole top, buck and rail, woven, chain link, electric wire, etc.? Type of fence helps the planner to understand which existing fences might be considered already mitigated for wildlife, or which ones need to be prioritized for alteration.
Wire Type, Number of Wires, and Wire Spacing	Wire type is typically smooth or barbed, but wire can include gauge, whether it is coated, wire condition, etc. Typically, as a fence has more wires, it is harder for certain types of wildlife passage. Document sections of fence and number of wires, include the current as-built wire spacings.
Brace Types, Post Materials	A tight, sturdy existing fence is a critical element of a fence that can be navigated by wildlife but also provides the necessary deterrent to livestock. Braces and line posts are essential to longevity and integrity of the fence. Document location and type of braces and posts and construction specifics and materials utilized.
Fence Condition	See below for a description of each: **Excellent** - Fence appears new or almost new. No wires are loose and braces and posts are firmly set and meet standards. **Good** - Materials are sturdy and functioning. A few posts or wires are loose and need operation and maintenance. **Fair** - Function as a livestock deterrent, but posts or wires may be loose. Several spots, or areas, are in need of repair and are generally considered above normal operation and maintenance. New materials are recommended, and some old materials may be salvageable. **Poor** - Wires and posts loose, rotting or failing. New materials needed and recommended. Minimal old materials are salvageable. **Non-Functioning** - Fence is no longer meeting its purpose. It is abandoned or not maintained. Sections are laying on the ground or have large openings.
Other Inventory Options	Areas where non-functioning fences may need to be removed. Terrain and slope where necessary. These factors are critical to fence specifications that might be needed to mitigate an existing fence or construct a new fence. Fences are more difficult to cross and can create negative areas of impact when they are placed across a steep slope or deep ditch. Fences on steep slopes become practically impossible for an animal to jump. Locate existing gates and document corner conditions. Gates may create difficult areas to navigate or can be used in a way to facilitate navigation. Old barbed wire fence corners can have multiple strands of wire or brace wires which can create possible areas of movement pinch points, but might need to be used for livestock management. Watering features that the fence will need to navigate and wildlife may disproportionately use. Signs of wildlife use, crossings (i.e., paths underneath fences, damage to wires by crossing), and evidence of animal impact (hair, carcasses, bones, etc.). Identify natural corridors and habitats, or areas where visual obstruction may occur.

Phase 2: Decision Support & Design

Improving fence passage for big game is best achieved by working towards a goal of minimizing structural fencing on the landscape as much as possible. Fewer fences not only benefits wildlife but also benefits the landowner's bottom line by reducing long-term costs associated with fence maintenance. While fences remain an important and required tool for livestock management and public safety, fences create significant short- and long-term costs for landowners (Knight et al. 2011). Although initial costs of new fences can be partly offset with Farm Bill programs or other financial assistance, long-term maintenance costs are a continuing burden carried by the landowner into the future that can increase financial risk and debt (Knight et al. 2011). Conservation plans that include additional fencing may not always make economic sense for landowners, so the return-on-investment should be carefully considered (Maher et al. 2023).

Conservationists can apply a thought process of 'avoid-minimize-mitigate' when helping producers evaluate options for reducing fence impacts (Box 3). Ideally, fence impacts on big game can be avoided entirely by utilizing alternative practices or technologies to control livestock. However, that may not always be feasible or desired. Where fences are determined to be necessary,

Box 3. Sequence for Reducing Fence Impacts

Avoid/Remove

- Avoid adding new fences to the landscape wherever practical.
- Consider the use of alternatives to structural fencing to address the resource concern or management objective.
- Remove fences that are no longer needed.

Minimize

- Consider reducing the amount of new fencing used.
- Use wildlife-friendlier fence designs. Avoid woven wire and other hazardous fence types.
- Strategically place, or relocate, fences into lower impact areas.

Mitigate

- Incorporate modifications into fences to facilitate big game passage in high impact areas.

there are several steps planners can take to minimize and mitigate impacts. Decision-support trees are provided below to help planners work with producers to evaluate alternatives to improving big game fence passage under three common scenarios: 1) new fences (Fig. 5), 2) existing but functional fences (Fig. 6), and 3) existing but non-functional fences (Fig. 7). Additional details on techniques and designs are then provided in the remainder of this section to support the selected alternative(s).

New Fences

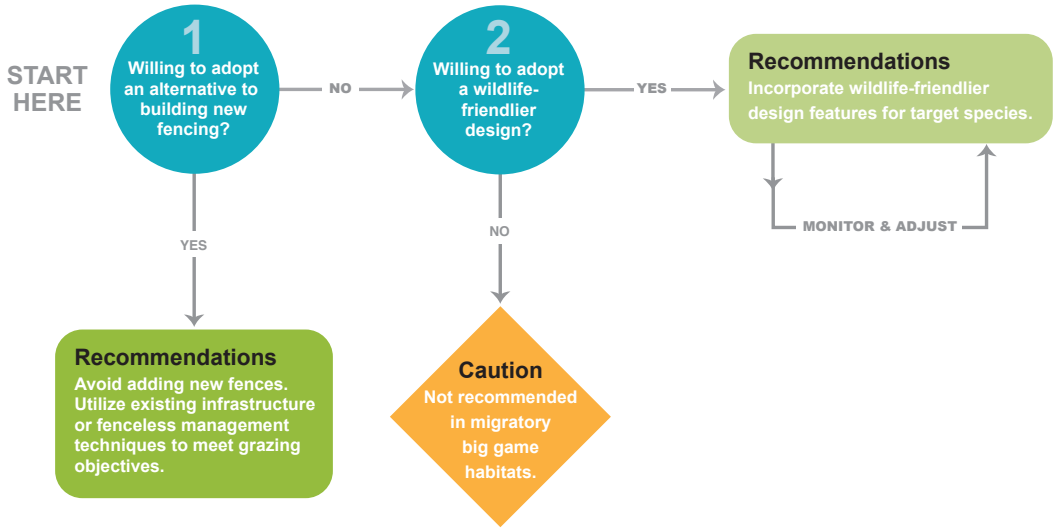


Figure 5. Decision process for new fences.

Existing, Functional Fences

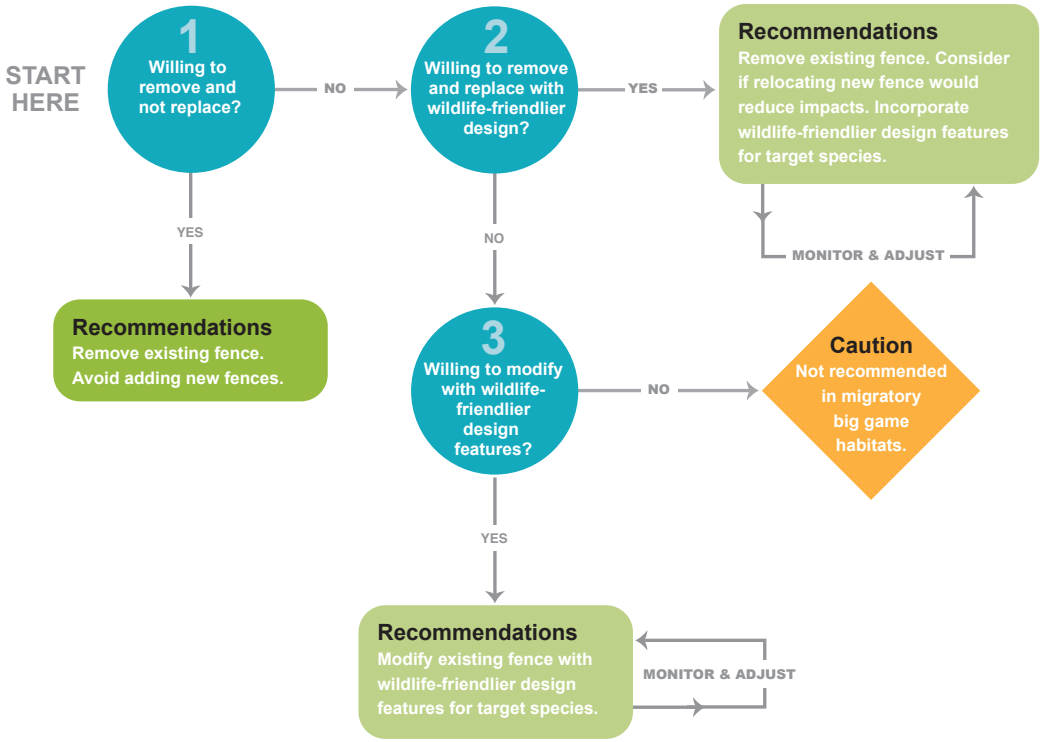


Figure 6. Decision process for existing, functional fences.

Existing, Non-Functional Fences

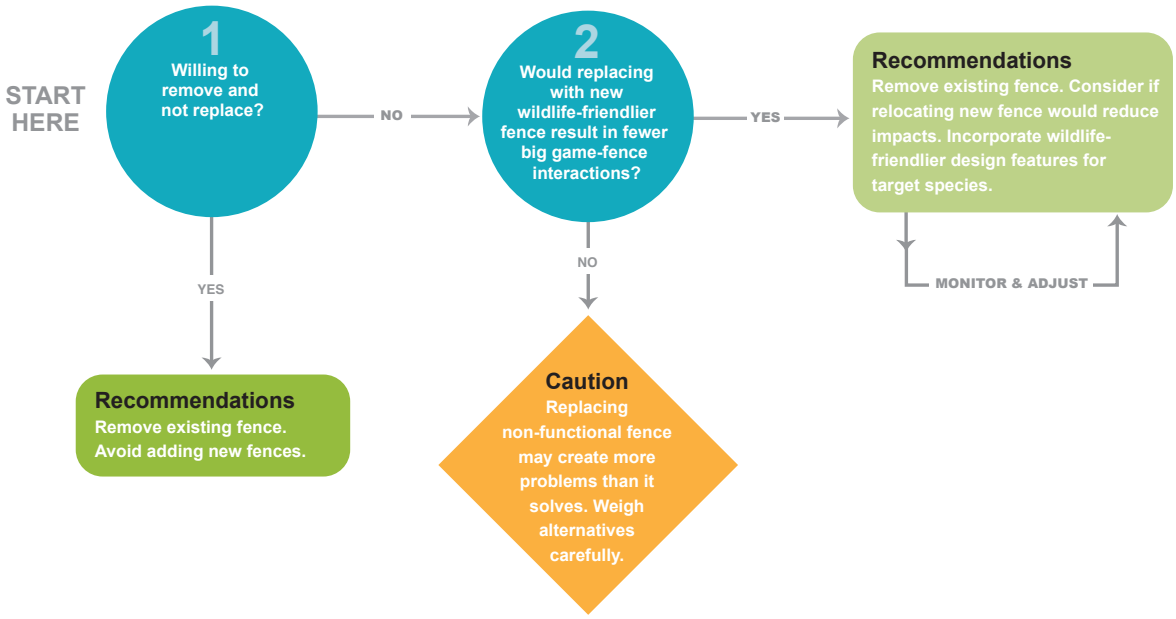


Figure 7. Decision process for existing, non-functional fences.

Avoiding and Removing Fences

Too often, fences are planned or replaced without a thorough assessment of needs, risks, and alternatives. Grazing management decisions need to be rooted in clear objectives and anticipated outcomes (Derner et al. 2022, USDA-NRCS 2022). Working with the producer to articulate ecological and financial goals and objectives leads to conversations on multiple alternatives that may be available to achieve desired outcomes. Flexible and well-considered stocking rates for available forage, considerations of stock density and utilizing grazing principles of intensity, frequency, timing, and duration of grazing with the plant community ecological site and resource objectives do not necessarily require more cross-fencing for pasture development and more intensive grazing rotation to achieve the objectives (Augustine et al. 2020, Wilmer et al. 2018). The addition of pastures utilizing fence construction should be carefully analyzed especially in areas that achieve heavy use by migratory big game. Inventory of the ranch's existing resources, infrastructure, goals and objectives will help determine if avoidance and reduction of fences is possible.

Follow these **avoidance** and **removal** strategies when developing alternatives to installing physical fences:

- On existing fences, identify areas where fences may no longer be needed and can be removed from the landscape. Unnecessary and dilapidated fences can create hazards to wildlife, livestock, and people. Obstruction Removal (CPS 500) is an NRCS conservation practice that can be used to remove old fences.

- Avoid building new fences by working with current infrastructure and utilizing flexible livestock stocking rates, density, timing, intensity, duration and frequency along with livestock preferences, and other critical ecological considerations. Utilize a stock and monitor approach, allowing monitoring of outcomes, triggers and checkpoints to drive adaptive decisions and adjustments to match objectives (Smith et al. 2016).

- Improve livestock distribution within the current pasture as available without additional fencing. Utilize water availability and supplementation (salt, protein)

or other strategic location of attractants (nutritional variability, shade, natural protection, etc.) to influence herd dynamics, distribution, and grazing patterns. Utilizing natural barriers in pasture configuration doesn't always create hard barriers for wildlife but can be effective methods for keeping livestock located in specific areas to achieve objectives. Utilize locally adapted livestock, breeding, and selective culling based on behavior to improve how a herd utilizes the landscape and alter grazing and browsing behaviors (Peterson 2014, Provenza 2008).

- Utilize fenceless management techniques to achieve desired livestock control, such as herding, range riding, or virtual fencing. The grazing management conservation practice (CPS 528) conservation practice allows landowners to manage vegetation with grazing and browsing animals with the intent to achieve specific ecological, economic and management objectives and does not necessarily require the use of physical fencing.

  Herding and/or range riding - Herding and/or range riding can be used effectively to manage livestock movements, resting areas, and grazing areas to meet management goals and objectives without construction of new fences. Herding will require a skilled rider who implements low-stress livestock handling (Cote 2004, Barnes 2014).

  Virtual fencing - Technology is quickly advancing to enable the use of virtual fencing in livestock management. Virtual fencing will reduce physical barriers to wildlife and allow control and movement of grazing animals (Golinski 2023). Virtual fencing utilizes an advanced GPS to create virtual fence lines and dynamically manage grazing management. Virtual fencing allows for highly flexible adaptive management with specific goals and objectives, riparian management, targeted grazing, fire and grazing management without the construction of new fences. (Boyd et al. 2022, 2023). For a discussion about practical applications of virtual fencing, see this **video** from the Rancher's Stewardship Alliance.

Minimizing and Mitigating Fence Impacts

If it has been determined that new physical fences are needed, then it is important to utilize the fence and wildlife information gathered during the inventory phase of the planning process. Remember, the NRCS national fence practice standard (CPS 382) currently requires that the design, locale, and installation of fences will be done to minimize impacts to wildlife. Problem fences are typically: too high to jump, too low to crawl under, have loose or broken wires, impale or snag leaping animals, result in collisions due to low visibility, or create a complete barrier to movement. Understanding the typical problems for migratory big game species in the local area allows planners to outline areas of the existing fence and new construction that need to minimize and mitigate fence impacts on wildlife.

Consider the following ***minimization*** and ***mitigation*** strategies to reduce fence impacts:

- Be sparing, creative, and judicious with the installation of new fencing. Before installing a new fence, determine if there are alternative locations that would reduce the potential impacts or overall amount of new fence needed.

- Avoid using woven wire and other hazardous fence types.

- Incorporate modifications into existing fences to facilitate big game passage (See Table 2 and Appendix 2). These may include removing wires, modifying existing wire heights, creating passage areas such as lay down fences, adjustable wires, and incorporating pole tops as necessary, etc. Structure for Wildlife (CPS 649) can be used to retrofit existing fences with wildlife mitigation strategies.

- Add additional gates and leave them open when livestock are not present in pasture to facilitate wildlife movement.

Adjustable wire fence for seasonal passage.

- Utilize wildlife-friendlier fence designs on new fences. (See Table 2 and Appendix 2)

- Consider adopting a state-wide policy and practice standard regarding use of wildlife-friendlier fence designs. For instance, Wyoming NRCS has historically and continues to require the use of wildlife-friendlier fences. Wyoming NRCS and partners primarily recommend and allow the construction of the following fences: standard barbed and barbless (with or without pole top), buck and pole, and permanent power fence. Specifications also include additional measures to minimize impacts. Limited exceptions to this policy are only made for targeted purposes like protection of windbreaks, critical areas, spring developments, and other special cases. For more details, see the Wyoming NRCS fence standard, implementation requirements, and job sheet in Section IV of the Wyoming NRCS Field Office Technical Guide.

- Keep in mind that the wildlife-friendlier designs presented here are the minimum to make fences safer based on what is known today. Give serious consideration to constructing fences with adjustable top and bottom wires to provide safer passage to migratory big game when livestock are not present and to provide management flexibility given the uncertainties surrounding wildlife-friendlier designs.

Keep in mind that the wildlife-friendlier designs presented here are the minimum to make fences safer based on what is known today.

Table 2. Summary of wildlife-friendlier fence design elements by species. Note that multiple species may need to be considered and a combination of measures may be required to reduce the fence impacts.

Species	Top wire height (in)	Top wire spacing (in)	Bottom wire height (in)	Visibility elements	Notes
Mule Deer	40 (42 max)	12 (10 min)	18 (16 min)	---	• Keep top two wires tight and adequately spaced apart • Barbless bottom wire • Lower top wire is better; 38 inches is encouraged
Pronghorn	NA	12 (10 min)	18 (16 min)	---	• Barbless bottom wire • More distance between ground and bottom wire is better
Elk	40 (42 max)	12 (10 min)	18 (16 min)	Yes	• Install top rail or other high visibility features in high use or low visibility areas • Top rail fence must be done in long stretches or they will simply do an end- run and cross where there is only wire • Barbless bottom wire • Lower top wire is better; 38 inches is encouraged
Bighorn Sheep	40 (42 max)	12 (10 min)	18 (16 min)	---	• 3-wire fence preferable • Barbless bottom wire
Moose	40 (42 max)	12 (10 min)	18 (16 min)	Yes	• Install top rail or other high visibility features in high use or low visibility areas such as thick willows • Barbless bottom wire • Lower fence height is better • Leave gates open in the spring to improve passage for moose calves
Sage Grouse	NA	NA	NA	Yes	• Install fence markers or other high visibility features

Other Considerations

On properly stocked rangelands, livestock pressure on fences is typically low. This allows the planner and producer to plan and design the least intrusive type of fence needed to achieve the required level of control by the kind and class of livestock animals being managed. Three-strand wire fence is usually adequate for effectively managing most livestock on rangelands. Four-strand wire fencing might be needed between neighbors or in pastures where mixing of herds is less desirable. However, it is often not essential to design fences for 100% containment of livestock, which provides flexibility in using fence heights and wire spacings to accommodate local wildlife use. Risk of livestock escapement from pastures needs to be weighed with the risk to wildlife.

The slope of the land that fences are placed on is another important consideration. As slope increases, fences become more of a barrier to big game passage (Fig. 8). Avoid running fences across slopes and ditches if possible or modify the design of the fence to adjust for slope effects. Ideally, fences should not be placed across steep slopes, but if unavoidable, lower the height of top wires and increase spacing on bottom wires. Incorporating adjustable wires is also a good minimization strategy on steeper slopes.

For strategic areas of high wildlife use, consider temporarily removing or mitigating barriers especially when the pasture is not in use by livestock. Let-down fences, additional gates, and adjustable wire fences can help minimize impacts when livestock are not in the pasture. These require labor and a commitment to regular management but provide significant big game benefits.

Electric wire is a viable option that can be easier for big game passage than traditional wire fences. Permanent power fence (12.5 gauge high-tensile wire) was found effective in management of cattle and bison and allowed elk, deer, and pronghorn to easily cross (Karhu and Anderson 2006). Electric wire can be removed seasonally to allow free passage. Electric wire is a useful option for excluding grazing from sensitive areas while allowing passage by wildlife or for areas where permanent fencing isn't desired. Understand livestock kinds, class, and grazing behavior so that wire is placed at effective heights. Effects of 2-, 3- and 4-wire high-tensile electric fence on wildlife have been researched and a 3-wire electric fence may be the most effective in areas with cattle or bison; heights studied in areas with livestock or bison management were 22" hot, 32" ground, and 42" hot (Karhu and Anderson 2006).

Fence stays are not recommended when managing with wildlife in mind. As stays age, they often lose effectiveness. Wires can become loose and slip on the stays and the stays can break or bend, which results in improper wire spacing or dimensional barrier issues. Standard fence designs with posts at 16.5' maintain tight wires, add to visibility, and allow for construction without stays.

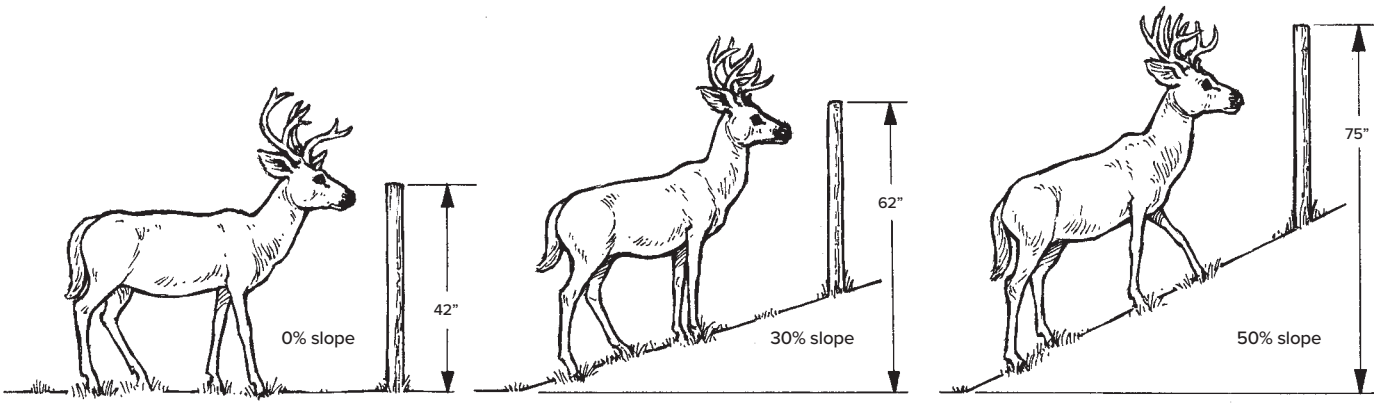


Figure 8. Slope increases effective height of fences (Paige (2015), illustrations by Ed Jenne, www.edjenne.com)

Fence visibility to wildlife can be affected by many factors such as wire type, landscape position, and vegetation. However, making every mile of fence highly visible is not desirable or necessary. Incorporation of high-visibility fence features should be done thoughtfully and strategically. High use areas during seasonal congregations or migrations are prime candidates for potential fence visibility concerns. Local knowledge, data, and field evidence (trails) can help inform where to target high-visibility features. Planners should consider the following three factors: 1) if animals are likely to cross, 2) where the animals are likely to cross, and 3) whether the animal will cross by going over or going under the fence (Jones 2020). It is important to consider running animals or low-flying birds, which need to see the fence at a distance that allows them to judge the height of the fence and decide on speed, route, and ability to successfully fly or jump over or crawl under the fence. Snow and vegetation can greatly impact the visibility of a fence. Planners may need to design multiple types of high-visibility features into a single stretch of fence. For example, a wire fence crossing a sagebrush flat may require marking near sage-grouse leks while the same fence passing through an aspen grove may require a pole top to reduce impacts to elk.

It is important to note that we still have much to learn about the effects of various high-visibility features, which further emphasizes the need to be judicious in their application. There is evidence that pronghorn and deer respond negatively to the use of short segments of PVC on the bottom wire, also known as 'goat bars' (Jones 2020). Also, the use of coated poly-wire has demonstrably negative impacts on migratory big game, which is known to cause entanglement that causes harm and potentially death.

Pole top fence. Sublette County, Wyoming.

Box 4. General Recommendations for Wildlife-Friendlier Landscapes

- Avoid adding new fences to the landscape wherever possible
- Where fencing is needed, be creative about placement to reduce the amount of potential impacts
- Remove unnecessary and non-functional fences from the landscape
- Lower the overall fence height
- Increase height of the bottom wire and use smooth wire
- Increase fence visibility in strategic, high-risk locations
- Incorporate let-down fence, adjustable-wire fence, or gates in strategic locations

Phase 3: Implementation

Conservation plans to improve big game passage may involve several practices, such as Obstruction Removal (CPS 500), Fence (CPS 382), Grazing Management (CPS 528), and Upland Wildlife Habitat Management (CPS 645), that work as a system to achieve desired outcomes. Implementation of the plan should adhere to the appropriate NRCS state-approved standards, along with site-specific specifications identified in the practice implementation requirements. Monitoring, maintenance, and adaptive management are essential, but often overlooked, elements of effective conservation plans. Below are some of the types of evaluation activities that may be needed.

Fence Monitoring, Operation, and Maintenance

Regular monitoring of fences is a necessary part of an ongoing plan to ensure fences are functioning as designed. At a minimum, NRCS standards require fences to have an operation and maintenance plan that includes:

- Conducting inspections of fences after storms and other disturbance events
- Repairing or replacing loose or broken material, gates, etc.
- Removing trees and limbs
- Repairing or replacing water gaps as necessary
- Repairing eroded areas
- Repairing or replacing markers or other safety and control features
- Maintaining marking or signage as necessary

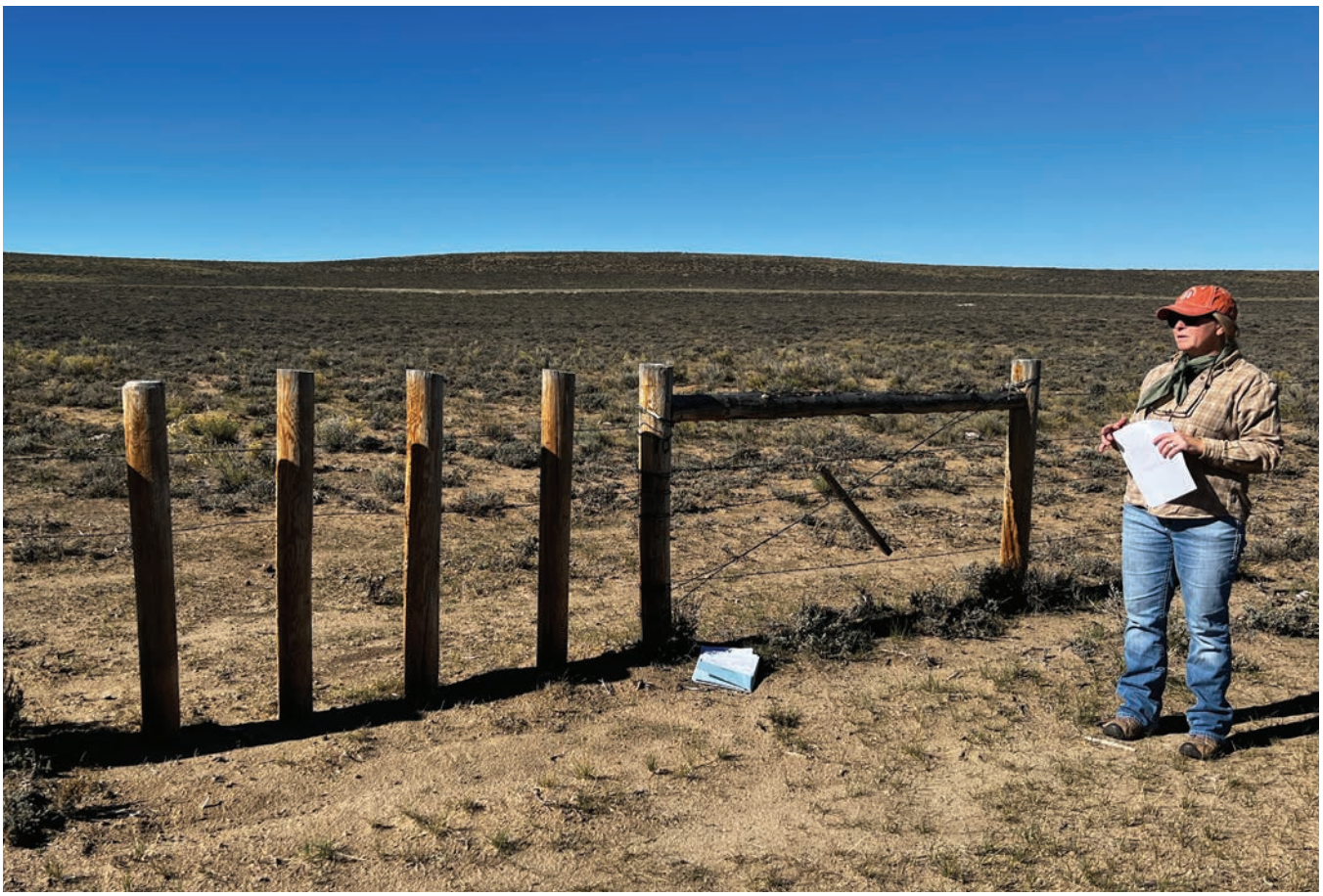
In addition to these basic requirements, additional fence monitoring, operation, and maintenance requirements specific to big game passage might include:

- Opening gates when pastures are not in use
- Looking for sagging wires and tightening as needed. Loose wires can entangle wildlife and livestock.
- Monitoring for new areas of heavy wildlife use or crossings and making appropriate adjustments
- Specifying where, when, and who will move adjustable wires during critical periods for migrating big game

Effectiveness Monitoring and Adaptive Management

Despite the widespread nature of fences on western landscapes, the science behind making fences friendlier for big game passage remains limited (Jakes et al. 2018). The conservation planning process and design alternatives presented in this technical note draw upon existing science and expertise of local land managers engaged in this work in Wyoming to help reduce the learning curve for others across the West. However, the myriad designs and contexts in which improved designs are applied make it difficult to prescribe uniform recommendations and quantify biological benefits of fence improvements. Given this uncertainty, conservation planners should approach this work with an adaptive management mindset. Every application of the techniques described in this document presents an opportunity to learn and fill knowledge gaps, providing the next landowner with additional or improved information.

Innovation and monitoring of new techniques should be encouraged. For example, the Bureau of Land Management and partners in the Upper Green Fence Initiative are actively piloting several new fence modification designs to provide additional options to meet big game and fence passage needs (D. Wooline, personal communication, October 2022). Creativity and innovation is particularly needed in challenging settings, such as road corridors and bison ranges, to find solutions that balance migratory big game needs with concerns related to safety and livestock health. The Conservation Innovation Program (CIG) may provide funding opportunities to pilot new concepts



Experimental 'slip gate" designs for migratory pronghorn being piloted by partners in Wyoming.

and designs. Findings from local testing of new techniques should be shared with NRCS state staff and partners as part of the adaptive management process to help improve state standards and specifications over time.

Where feasible, landowner monitoring and evaluation of big game and fence interactions should be included as part of the conservation plan. Some basic monitoring can be effectively conducted by landowners and partners such as, establishing camera traps at key crossings or simply documenting observations of how wildlife are interacting with wildlife-friendlier fence improvements. Insights from these observations should be discussed with planners and partners to determine if design adjustments need to be made to address local conditions.

Large-scale efforts to improve big game passage of fences also present opportunities for more rigorous learning through co-produced science (Naugle et al. 2020). For example, the USDA-Wyoming Big Game Conservation Partnership is coupling targeted Farm Bill program financial and technical assistance with science support through USDA's Conservation Effects Assessment Project (CEAP) to enlist the help of researchers at the University of Wyoming to test efficacy of wildlife-friendlier fence designs and quantify benefits for big game. When engaged in an area-wide effort or initiative to improve fences for wildlife, teaming up with universities or other researchers early in project planning can help partners with addressing knowledge gaps and uncertainties while also evaluating biological outcomes of their conservation efforts. Furthermore, linking outcomes with communications (e.g., videos, stories, **social media**) to share on-the-ground successes helps raise awareness and garner further support to scale up conservation.

References

Barnes, M. (2015). Low-stress herding improves herd instinct, facilitates strategic grazing management. *Stockmanship Journal,* 4(1), 31-43.

Berger, J., & Cain, S. L. (2014). Moving beyond science to protect a mammalian migration corridor. *Conservation Biology,* 28(5), 1142-1150.

Boyd, C. S., O'Connor, R., Ranches, J., Bohnert, D. W., Bates, J. D., Johnson, D. D., ... & Doherty, K. E. (2022). Virtual fencing effectively excludes cattle from burned sagebrush steppe. *Rangeland Ecology & Management,* 81, 55-62.

Boyd, C. S., O'Connor, R. C., Ranches, J., Bohnert, D. W., Bates, J. D., Johnson, D. D., ... & Doherty, K. E. (2023). Using virtual fencing to create fuel breaks in the sagebrush steppe. *Rangeland Ecology & Management,* 89, 87-93.

Burkholder, E. N., Jakes, A. F., Jones, P. F., Hebblewhite, M., & Bishop, C. J. (2018). To jump or not to jump: mule deer and white-tailed deer fence crossing decisions. *Wildlife Society Bulletin,* 42(3), 420-429.

Buzzard, S. A., Jakes, A. F., Pearson, A. J., & Broberg, L. (2022). Advancing fence datasets: Comparing approaches to map fence locations and specifications in southwest Montana. *Frontiers in Conservation Science,* 3, 126.

Cote, S. (2004). *Stockmanship: a powerful tool for grazing lands management.* USDA Natural Resources Conservation Service.

Augustine, D. J., Derner, J. D., Fernández-Giménez, M. E., Porensky, L. M., Wilmer, H., & Briske, D. D. (2020). Adaptive, multipaddock rotational grazing management: a ranch-scale assessment of effects on vegetation and livestock performance in semiarid rangeland. *Rangeland Ecology & Management,* 73(6), 796-810.

Derner, J. D., Budd, B., Grissom, G., Kachergis, E. J., Augustine, D. J., Wilmer, H., ... & Ritten, J. P. (2022). Adaptive grazing management in semiarid rangelands: An outcome-driven focus. *Rangelands*, 44(1), 111-118.

Gigliotti, L. C., Xu, W., Zuckerman, G. R., Atwood, M. P., Cole, E. K., Courtemanch, A., ... & Middleton, A. D. (2022). Wildlife migrations highlight importance of both private lands and protected areas in the Greater Yellowstone Ecosystem. *Biological Conservation,* 275, 109752.

Goliński P, Sobolewska P, Stefańska B, Golińska B. (2023) Virtual Fencing Technology for Cattle Management in the Pasture Feeding System—A Review. *Agriculture*. 13(1):91. **https://doi.org/10.3390/agriculture13010091**.

Harrington, J. L., & Conover, M. R. (2006). Characteristics of ungulate behavior and mortality associated with wire fences. *Wildlife Society Bulletin,* 34(5), 1295-1305.

Jakes, A. F., Gates, C. C., DeCesare, N. J., Jones, P. F., Goldberg, J. F., Kunkel, K. E., & Hebblewhite, M. (2018a). Classifying the migration behaviors of pronghorn on their northern range. *The Journal of Wildlife Management,* 82(6), 1229-1242.

Jakes, A. F., Jones, P. F., Paige, L. C., Seidler, R. G., & Huijser, M. P. (2018b). A fence runs through it: A call for greater attention to the influence of fences on wildlife and ecosystems. *Biological Conservation,* 227, 310-318.

Jones, P. F. (2014). Scarred for life: the other side of the fence debate. *Human-Wildlife Interactions,* 8(1), 150-154.

Jones, P. F., Jakes, A. F., Eacker, D. R., Seward, B. C., Hebblewhite, M., & Martin, B. H. (2018). Evaluating responses by pronghorn to fence modifications across the Northern Great Plains. *Wildlife Society Bulletin,* 42(2), 225-236.

Jones, P. F., Jakes, A. F., MacDonald, A. M., Hanlon, J. A., Eacker, D. R., Martin, B. H., & Hebblewhite, M. (2020). Evaluating responses by sympatric ungulates to fence modifications across the northern Great Plains. *Wildlife Society Bulletin,* 44(1), 130-141.

Karhu, R. R., & Anderson, S. H. (2006). The effect of high-tensile electric fence designs on big-game and livestock movements. *Wildlife Society Bulletin,* 34(2), 293-299.

Kauffman, M. J., Copeland, H. E., Cole, E., Cuzzocreo, M., Dewey, S., Fattebert, J., ... & Thonhoff, M. (2020). *Ungulate migrations of the western United States, volume 1:* US Geological Survey data release. U*S Geological Survey*. **https://doi. org/10.5066/P9O2YM6I**.

Kauffman, M., Lowrey, B., Beck, J., Berg, J., Bergen, S., Berger, J., … & Tatman, N. (2022a). *Ungulate migrations of the western United States, volume 2:* U.S. Geological Survey Scientific Investigations Report 2022–5008, 160 p., **https://doi.org/10.3133/sir20225008**.

Kauffman, M., Lowrey, B., Berg, J., Bergen, S., Brimeyer, D., Burke, P., ... & Wolf, L. (2022b). *Ungulate migrations of the western United States, volume 3* (No. 2022-5088). US Geological Survey. **https://doi.org/10.3133/sir20225088**.

Knight, K. B., Toombs, T. P., & Derner, J. D. (2011). Cross-fencing on private US rangelands: financial costs and producer risks. *Rangelands*, 33(2), 41-44.

Løvschal, M., Bøcher, P. K., Pilgaard, J., Amoke, I., Odingo, A., Thuo, A., & Svenning, J. C. (2017). Fencing bodes a rapid collapse of the unique Greater Mara ecosystem. *Scientific Reports,* 7(1), 41450.

Løvschal, M., Juul Nørmark, M., Svenning, J. C., & Wall, J. (2022). New land tenure fences are still cropping up in the Greater Mara. *Scientific Reports,* 12(1), 11064.

Maher, A. T., Ashwell, N. E. Q., Tanaka, J. A., Ritten, J. P., & Maczko, K. A. (2023). Financial barriers and opportunities for conservation adoption on US rangelands: A region-wide, ranch-level economic assessment of NRCS-sponsored Greater Sage-grouse habitat conservation programs. *Journal of Environmental Management,* 116420.

Middleton, A. D., Merkle, J. A., McWhirter, D. E., Cook, J. G., Cook, R. C., White, P. J., & Kauffman, M. J. (2018). Green-wave surfing increases fat gain in a migratory ungulate. *Oikos*, 127(7), 1060-1068.

Middleton, A. D., Sawyer, H., Merkle, J. A., Kauffman, M. J., Cole, E. K., Dewey, S. R., ... & White, P. J. (2020). Conserving transboundary wildlife migrations: recent insights from the Greater Yellowstone Ecosystem. *Frontiers in Ecology and the Environment,* 18(2), 83-91.

Naugle, D. E., Allred, B. W., Jones, M. O., Twidwell, D., & Maestas, J. D. (2020). Coproducing science to inform working lands: The next frontier in nature conservation. *BioScience,* 70(1), 90-96.

Natural Resources Conservation Service (NRCS). (2021a). National Planning Procedures Handbook (NPPH), Amendment 9. Title 180. USDA-NRCS. Washington, D.C. **https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=47643.wba**

Natural Resources Conservation Service (NRCS). (2021b). A framework for conservation action in the Sagebrush Biome. Working Lands for Wildlife, USDA-NRCS. Washington, D.C. Available at: **https://www.wlfw.org/wp-content/uploads/2022/11/SagebrushFramework.pdf**.

Natural Resource Conservation Service (NRCS). (2022). Wyoming Conservation Practice Standard Fence. USDA-NRCS Wyoming. Available at: **Conservation Practice Standard Fence (Code 382) (usda.gov)**

Paige, C. (2015). A Wyoming Landowner's Handbook to Fences and Wildlife: Practical Tips for Fencing with Wildlife in Mind. Wyoming Community Foundation, Laramie, WY. 56 pp. **https://extension.colostate.edu/wp-content/uploads/2022/01/A-Wyoming-Landowners-Handbook-to-Fences-and-Wildlife_2nd-Edition_-lo-res.pdf**

Petersen, C. A., Villalba, J. J., & Provenza, F. D. (2014). Influence of experience on browsing sagebrush by cattle and its impacts on plant community structure. *Rangeland Ecology & Management,* 67(1), 78-87.

Provenza, F. D. (2008). What does it mean to be locally adapted and who cares anyway?. *Journal of Animal Science,* 86 (suppl_14), E271-E284.

Sawyer, H., Kauffman, M. J., Nielson, R. M., & Horne, J. S. (2009). Identifying and prioritizing ungulate migration routes for landscape-level conservation. *Ecological Applications,* 19(8), 2016-2025.

Sawyer, H., & Kauffman, M. J. (2011). Stopover ecology of a migratory ungulate. *Journal of Animal Ecology,* 80(5), 1078-1087.

Sawyer, H., Kauffman, M. J., Middleton, A. D., Morrison, T. A., Nielson, R. M., & Wyckoff, T. B. (2013). A framework for understanding semi-permeable barrier effects on migratory ungulates. *Journal of Applied Ecology,* 50(1), 68-78.

Sawyer, H., Middleton, A. D., Hayes, M. M., Kauffman, M. J., & Monteith, K. L. (2016). The extra mile: Ungulate migration distance alters the use of seasonal range and exposure to anthropogenic risk. *Ecosphere*, 7(10), e01534.

Scott, M. D. (1992). Buck-and-pole fence crossings by 4 ungulate species. *Wildlife Society Bulletin (1973-2006),* 20(2), 204-210.

Segar, J., & Keane, A. (2020). Species and demographic responses to wildlife-friendly fencing on ungulate crossing success and behavior. *Conservation Science and Practice,* 2(10), e285.

Smith, L., Ruyle, G. B., Maynard, J., Barker, S., Meyer, W., Stewart, D., ... & Dyess, J. (2007). Principles of obtaining and interpreting utilization data on rangelands. *University of Arizona,* Cooperative Extension Service.

Stevens, B. S., J. W. Connelly, and K. P. Reese. (2012a). Multi-scale assessment of greater sage-grouse fence collision as a function of site and broad scale factors. *Journal of Wildlife Management.* 76(7):1370-1380.

Stevens, B. S., K. P. Reese, J. W. Connelly, and D. D. Musil. (2012b). Greater sage-grouse and fences: Does marking reduce collisions? *Wildlife Society Bulletin,* 36, 297-303.

Stevens, B. S., Naugle, D. E., Dennis, B., Connelly, J. W., Griffiths, T., & Reese, K. P. (2013). Mapping sage-grouse fence-collision risk: spatially explicit models for targeting conservation implementation. *Wildlife Society Bulletin,* 37(2), 409-415.

Taylor, P. D., Fahrig, L., Henein, K., & Merriam, G. (1993). Connectivity is a vital element of landscape structure. *Oikos*, 571-573.

USDA-NRCS. (2022). National Range and Pasture Handbook. Handbook Number 65.

Wiens, J. A. (1989). Spatial scaling in ecology. *Functional ecology,* 3(4), 385-397.

Xu, W., Dejid, N., Herrmann, V., Sawyer, H., & Middleton, A. D. (2021). Barrier Behaviour Analysis (BaBA) reveals extensive effects of fencing on wide-ranging ungulates. *Journal of Applied Ecology*, 58(4), 690-698.

Xu, W., Gigliotti, L. C., Royauté, R., Sawyer, H., & Middleton, A. D. (2023). Fencing amplifies individual differences in movement with implications on survival for two migratory ungulates. *Journal of Animal Ecology,* 92(3), 677-689.

Appendices

Appendix 1. Ranking sheet to prioritize funding for big game fence improvements through the Upper Green Fence Initiative. Courtesy of Wyoming Fish and Game Department.

ECOLOGICAL IMPACT		
Factor	**Type**	**Score (0 or 1)**
Big Game Crucial Range	Pronghorn	
	Elk	
	Mule Deer	
	Moose	
	Bighorn Sheep	
Mule Deer	Migration	
	MDI Herd Unit	
Pronghorn	Migration	
Habitat Priority	Terrestrial Restoration Area	
	Score (out of 65)	**Total Points *7.23 weight**

CURRENT FENCE CONDITION		
Type		**Score (0 or 1) * weight**
Woven Wire		*25
Barbed Wire	>4 strands	*6
	Bottom strand <16”	*8
	>42” tall	*8
Other		*23
	Score (out of 25)	

BONUS		Score (5 pts. each)
1	Project incorporates planned removal with no intention to rebuild	
2	Landowner able to provide contributions	
	Score (out of 10)	

TOTAL PROJECT RANKING (out of 100)

OTHER CONSIDERATIONS		
Replacement potential	Is the project a complete tear out and rebuild?	Y/N
	Is the project a modification only or has the potential to incorporate modifications as opposed to re-constructions?	Y/N
Landowner contributions	If the landowner is able to provide a contribution, what percent of total cost?	Percent of cost
	Landowner willing to sign agreement for long-term maintenance?	Y/N
Comments		

INSTRUCTIONS - ECOLOGICAL IMPACT RANKING	
Big Game Crucial Ranges	If any of the project boundary overlaps with an identified crucial range, the project shall receive a score of 1.
Mule Deer	**Migration:** If any of the project boundary intersects a designated mule deer migration corridor or identified migration route OR is within one (1) mile of a corridor or route, the project shall receive a score of 1. **Mule Deer Initiative (MDI) Herd Unit:** If any of the project boundary falls with an MDI herd, the project shall receive a score of 1.
Pronghorn	**Migration:** If any of the project boundary intersects an identified prong horn migration route OR is within one (1) mile of a route, the project shall receive a score of 1.
Habitat Priority	**Terrestrial Restoration Areas:** If any of the project boundary falls within the WGFD Strategic Habitat Plan - Terrestrial Restoration Areas, the project shall receive a score of 1.

Current Fence Condition

1) At least 50% of identified fences must be, on average, in the condition as the category selected. If selected, the project shall receive a score of 1. (Example: For the category "Woven Wire" to be selected, 50% of all fences must contain woven wire fencing.)

2) Only 1 category may be selected from the options provided. (Example: If "Barbed Wire" is chosen, then "Woven Wire" and "Other" may not be selected.)

3) Under Barbed Wire, all or none of the options (greater than 4 strand, less than 16", and greater than 42" tall) may be selected.

4) Category "Other": This option is meant to capture various fence types or conditions that are not often encountered, but still may pose a barrier to wildlife. (Example: Fence sections that are known problem areas for wildlife (such as high amounts of entanglements), Buck & Rail, or other fence types deemed impermeable.)

Bonus Criteria

To further break out projects, an additional two bonus questions were added. If the project incorporates any permanent fence removal an additional 5 points will be given. Additionally, if the landowner is able to provide contribution (labor, materials, financial) the project shall receive 5 additional points.

Other Considerations

This section is meant to capture other relevant information that project managers may take into consideration for final project rankings. If the Landowner is unwilling to sign an agreement for long-term maintenance, then this essentially disqualifies them from financial assistance. Comments section should be used to capture any other information important to the project.

Definitions

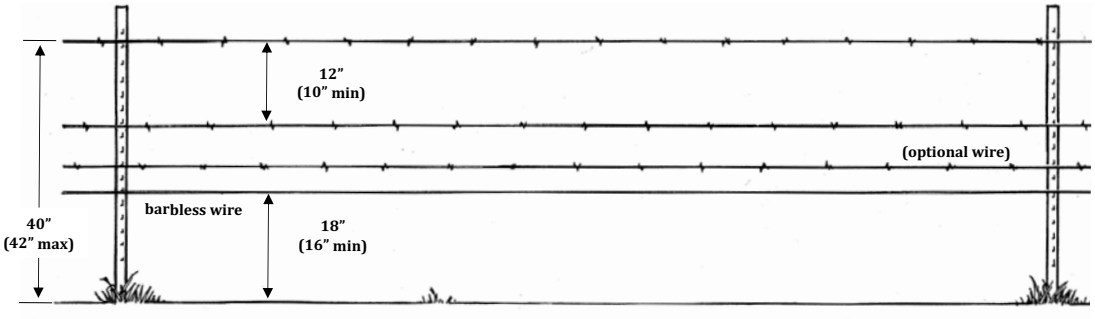
Crucial Ranges: Crucial ranges are those areas of big game habitat that have been documented as one of the limiting factors in a population's ability to maintain itself at a certain level over the long-term.

Mule Deer Initiative Herd: Herd units prioritized in the Wyoming Mule Deer Initiative, which was formally adopted in 2007. This initiative outlines the issues affecting deer management now and in the future, identifies appropriate goals and objectives to address mule deer management issues, and recommends strategies to improve mule deer management in Wyoming.

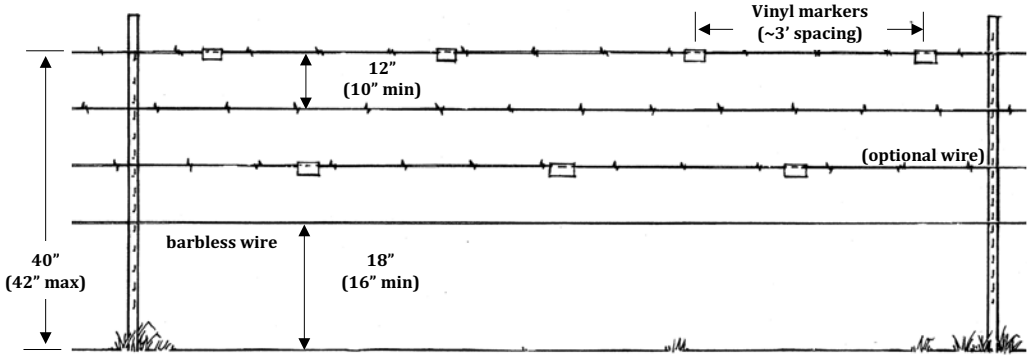
Terrestrial Restoration Area: Important terrestrial wildlife habitats that can and should be actively restored to achieve greater wildlife value.

Appendix 2. Standard drawings for wildlife-friendlier fence designs, including adjustable wire fence and lay-down fence for seasonal big game passage. Modified from Paige (2015), illustrations by Ed Jenne www.edjenne.com.

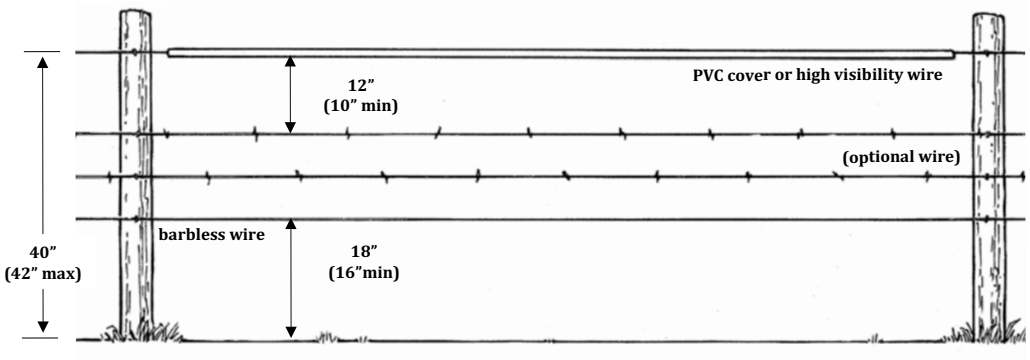
Barbed/Barbless Wire Fence



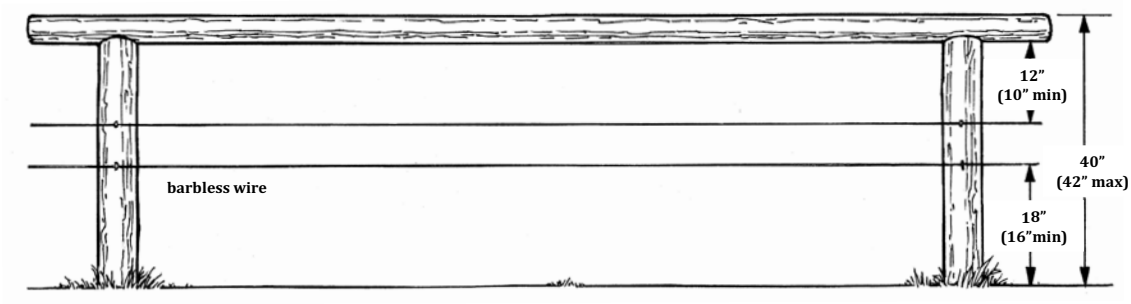
Barbed/Barbless Wire Fence - Visibility Markers



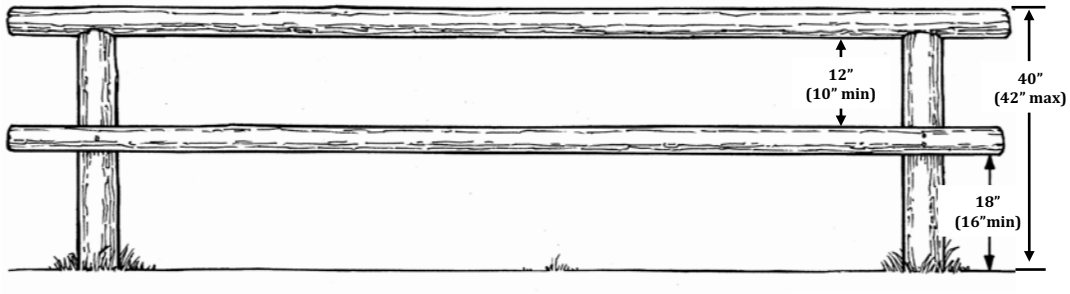
Barbed/Barbless Wire Fence - High Visibility



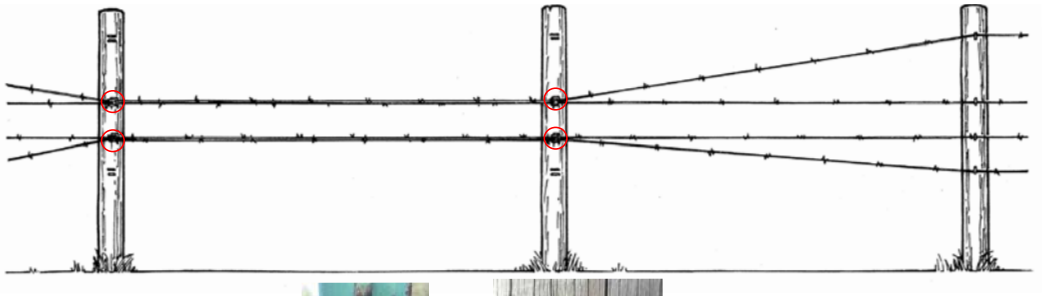
Pole Top/Barbless Wire Fence



Pole Fence



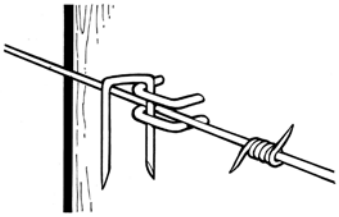
Adjustable Wire Fence



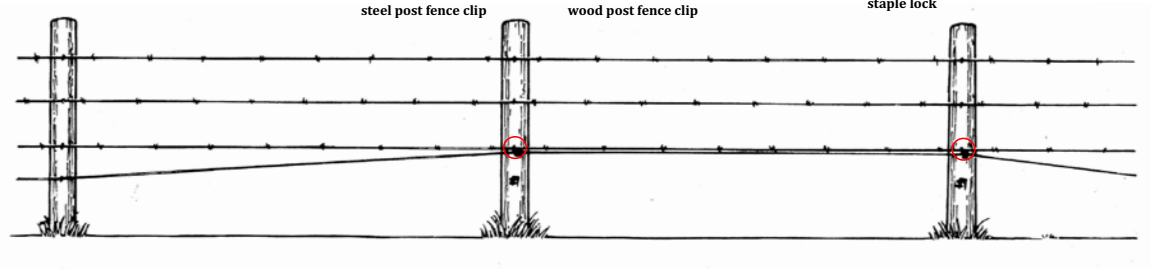
Fence clips or staple locks are installed to adjust top, bottom, or top and bottom wire heights to facilitate seasonal big game crossings

steel post fence clip

wood post fence clip



staple lock



Lay Down Fence