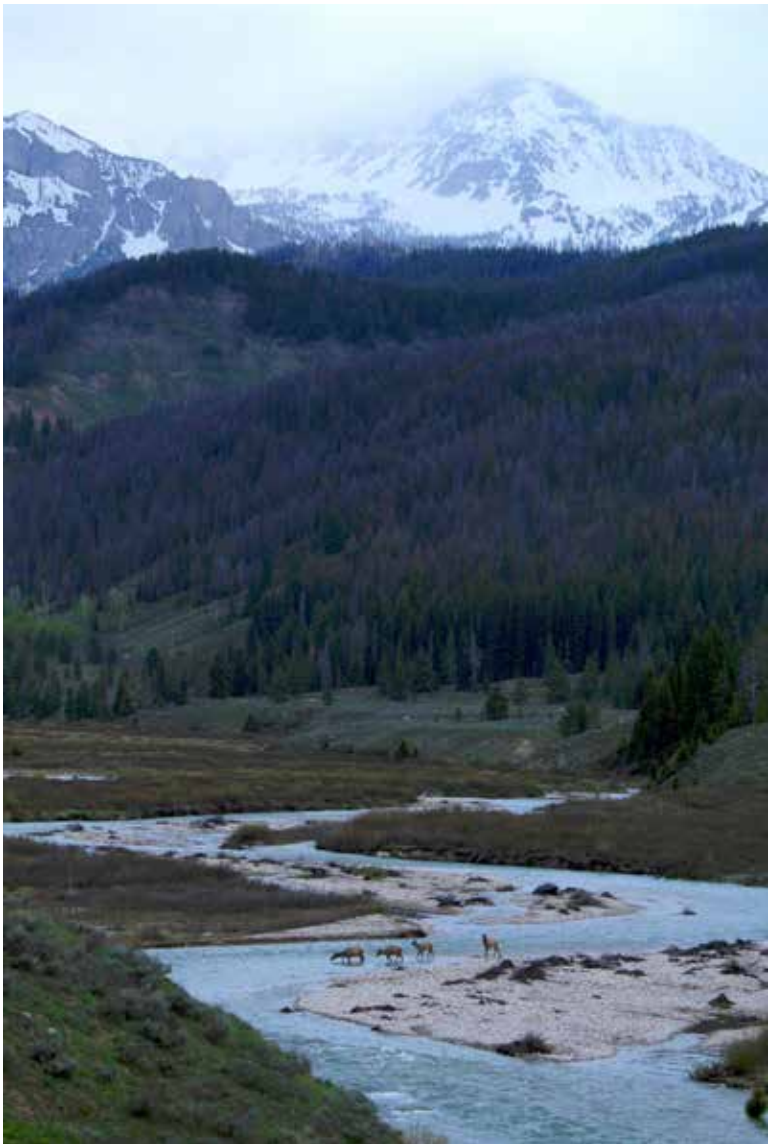

Conservation Assessment of Big Game Migration on Wyoming's Bridger-Teton National Forest

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Pew's U.S. Public Lands and Rivers Conservation initiative aims to conserve ecologically and culturally significant public landscapes by collaborating with local communities, businesses, government officials, and other stakeholders to achieve balanced, commonsense policy at the federal and state level. Identifying and conserving wildlife migration corridors is an important part of our work. www.pewtrusts.org/wildlifecorridors

Photos (clockwise starting upper left): Migratory elk crossing Granite Creek, Bridger-Teton National Forest, Wyoming, Gregory Nickerson, Wyoming Migration Initiative/University of Wyoming; Bull elk migrating in Shoshone National Forest, Travis Zaffarano, Wyoming Migration Initiative/University of Wyoming Cooperative Fish and Wildlife Research Unit; WMI biologist Travis Zaffarano replaces batteries in Bushnell Trail, Gregory Nickerson; Mule deer doe, Red Desert to Hoback Migration Corridor, Wyoming, Gregory Nickerson

Introduction

The Bridger-Teton National Forest (BTNF; Figure 1) encompasses a significant portion of the Greater Yellowstone Ecosystem, the largest remaining intact ecosystem in the contiguous U.S. (USFS Bridger-Teton NF 2021). The more than 3.4 million-acre national forest is home to pristine watersheds, abundant wildlife, 1.3 million acres of wilderness, numerous outdoor recreation opportunities, nearly 1.4 million acres of roadless areas, 112,000 acres of wilderness study areas, and thousands of miles of unspoiled, free flowing rivers (USFS Bridger-Teton NF 2021).

The BTNF is divided into six Ranger Districts, Kemmerer, Big Piney, Greys River, Jackson, Blackrock, and Pinedale Ranger Districts (USFS Bridger-Teton NF Districts 2021). Management efforts are coordinated among the districts through the land and resource management plan, or "forest plan." The National Forest Management Act (NFMA) and

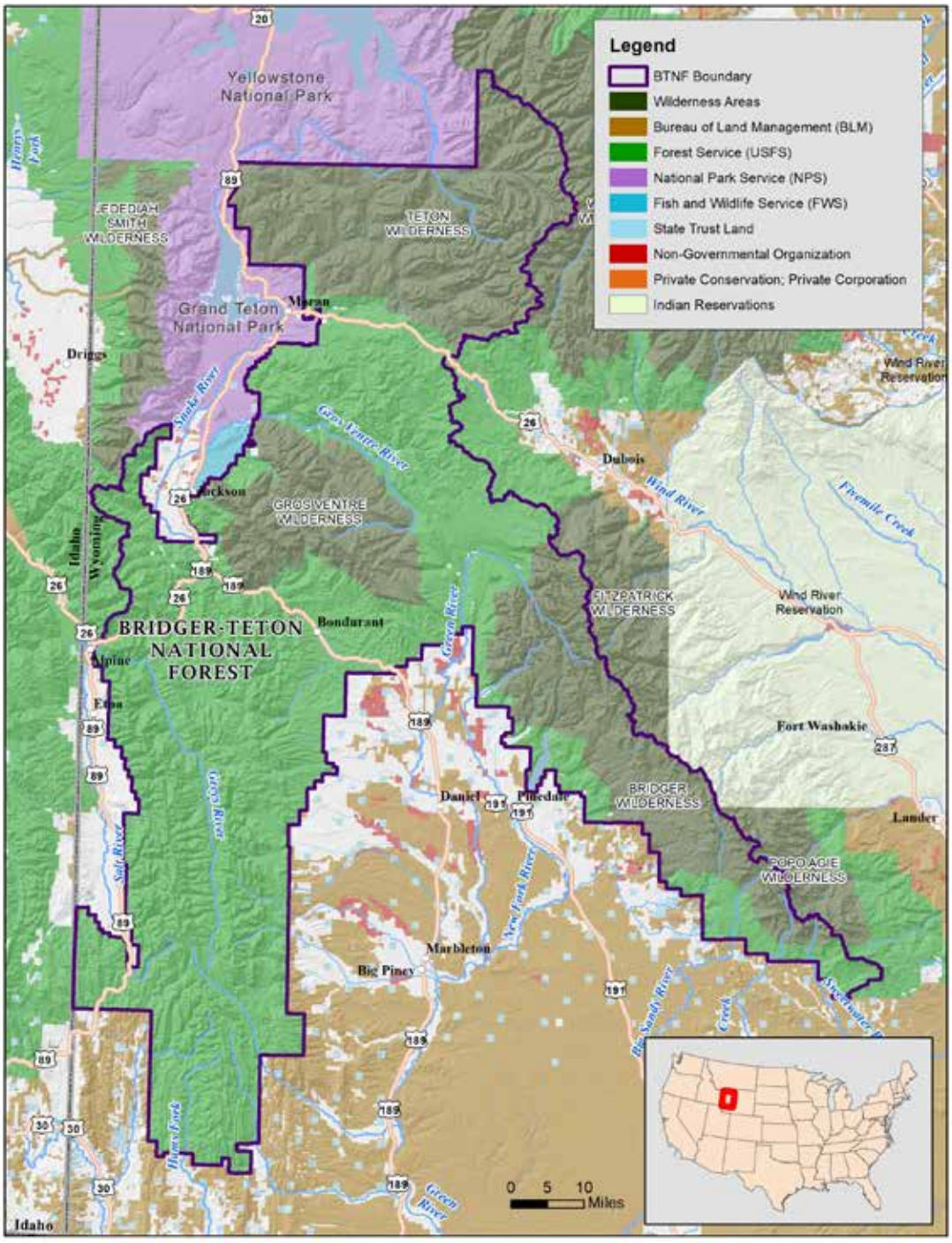


Figure 1: Bridger Teton National Forest Overview Map

National Forest System land management planning regulations ("2012 planning rule") establish a process for developing and revising forest plans, and set requirements for supporting ecological integrity through the implementation of those forest plans (36 C.F.R. §§ 219.1-219.19). Under the NFMA, forest plans provide frameworks for balancing conservation of wildlife habitat and human enterprise. In addition, the NFMA explicitly requires managing national forest lands for ecological connectivity, and promoting connectivity across land ownership (36 C.F.R. §§ 219.1-219.19).

When implemented regularly, these frameworks are intended to provide a large-scale, adaptive approach to resource management and allows the U.S. Forest Service to keep plans current; respond to new data and research, as well as changing conditions. The Forest Service assesses the existing economic, social, and ecological conditions and trends in and around the national forest when generating and revising forest plans.

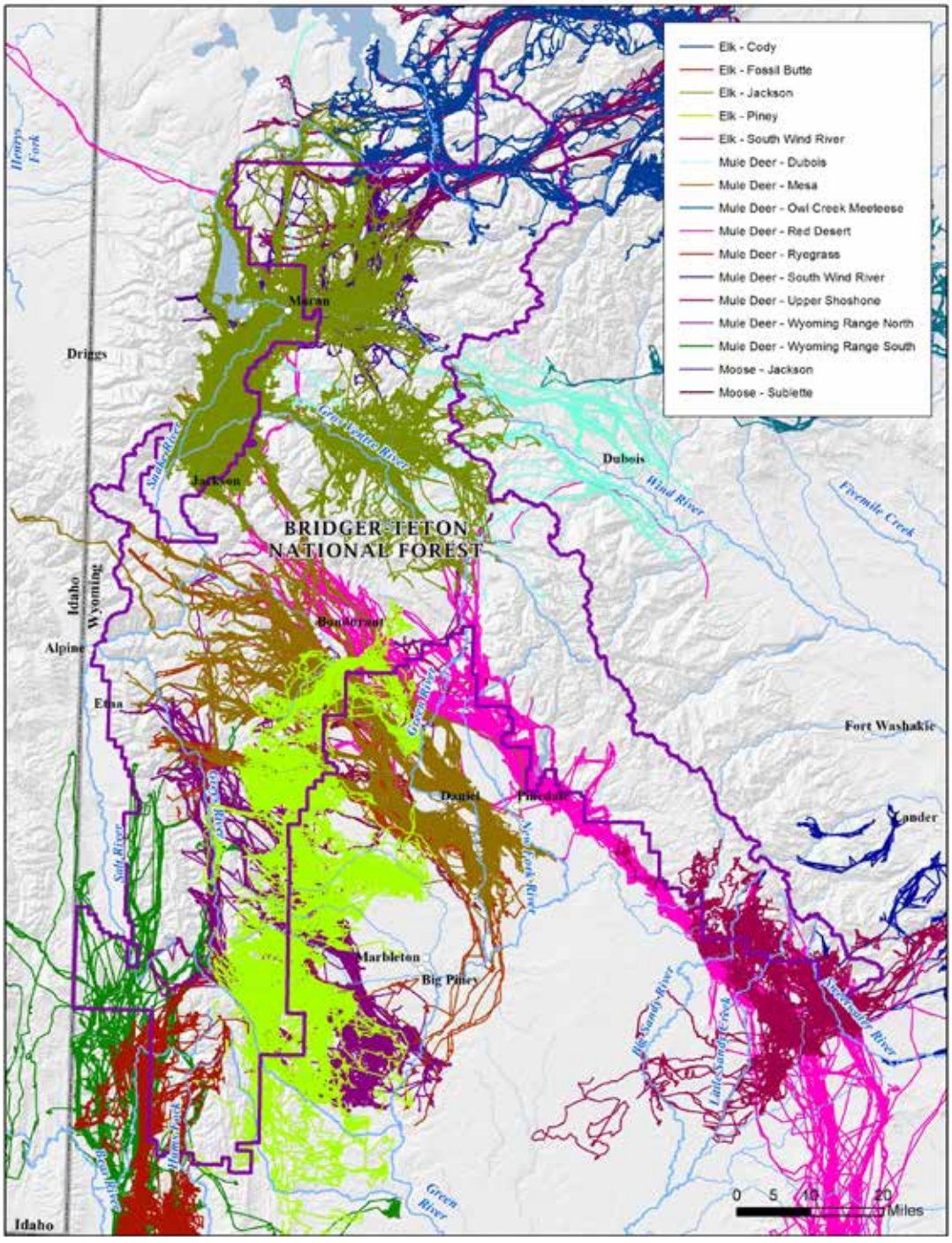


Figure 2: GPS collar tracks

During the assessment process, the Forest Service compiles the best available data from a variety of sources, including Federal and State agencies, tribes, researchers, and the public, as well as state forest assessments and strategies, outdoor recreation plans, community wildfire protection plans, public transportation plans, and state and tribal wildlife management plans (Federal Advisory Committee 2016). This information is used to inform plan decisions.

Perhaps one of the most important ecological processes this type of adaptive approach can benefit is wildlife migration. Ungulate species, such as mule deer, elk, bighorn sheep, Rocky Mountain goat, and moose, typically migrate from high elevation summer range, where snow-fed forage is seasonally abundant, to lower elevation winter grounds, as cool autumn weather begins to set in. In the spring, when the snows retreat and plants begin to grow in the high country, the ungulates reverse course and travel from low elevation winter range back to higher summering grounds. Tracking seasonal resources enhances foraging opportunities and reduces exposure to harsh conditions (Bolger et al. 2008, Middleton et al. 2018). When ungulates aren't able to appropriately follow resources, they suffer from elevated energy, failure to gain sufficient fat for the winter, reduced reproductive output, and mortality (Bolger et al. 2008, Kauffman et al. 2018, Middleton et al. 2018, Kauffman et al. 2020).

Migration allows ungulates to survive in otherwise harsh, seasonal landscapes and vary in the distance traveled. For example, mule deer movements range from 10 to 150 miles (Kauffman et al. 2020). The longer the movement pathway, the more likely it is to encounter barriers, such as increases in roads, human activities, fencing, and other development, as well as exotic species invasion and changing climactic regimes. Preserving connectivity along migration routes, and resources within the pathway will help protect big game. Equally important is protecting stopover sites, where ungulates spend much of their time during migration. For example, mule deer spend roughly 95% of a migration journey is spent foraging at stopovers, where habitat quality is highest along the migration route (Sawyer and Kauffman 2011). These areas are used year after year, and provide an important early spring forage resource. Calving and lambing grounds, crucial range, and other places where sensitive behaviors occur are also areas that are important to identify and conserve.

Losing the ability to migrate has led, and could lead, to sudden and dramatic declines in ungulate populations (Bolger et al. 2008). For example, wildebeest and hartebeest populations declined by 70–95% in the decade or two following the disruption of their migration routes (Bolger et al. 2008). It is vital that corridors be preserved before these routes are lost, along with individual animals that know the route and can pass that knowledge on to future generations (Kauffman et al. 2020). Since animals must learn to migrate, if a migration route is interrupted, scientists predict that it will take many generations for ungulates to relearn the pathway (Jesmer et al. 2018), while in other cases, historic migratory diversity may not recover (Lowrey et al. 2020).

In addition to physical barriers, facilitating migration requires navigating socio-political and logistical hurdles. Effectively facilitating migration requires coordination among many different partners, such as wildlife biologists and land managers; government, research, industry and residents; state, federal, and tribal governments; etc.

The BTNF contains important movement corridors and is a critical area for supporting ungulate migration (Figure 2). With the help of strong local research efforts, some migration routes, such as the Sublette Mule Deer Corridor, have been identified and officially designated for conservation by the State of Wyoming (WGFD 2017). However, development can jeopardize important routes. When disturbed by human activities or development, ungulates may move through areas faster, detour around disturbances, and reduce their use of stopover areas, which are critical habitat patches along the migration route in which animals rest and forage (Sawyer et al. 2013, Middleton et al.

2018). These changes in behavior can have profound impacts on migration and result in spatial restrictions in corridors or a mismatch between migration timing and the time when spring forage quality is highest. This temporal mismatch may hamper an animal's ability to access newly emergent spring forage, reducing their ability to accumulate sufficient fat reserves (Sawyer et al. 2013, Middleton et al. 2018). Given the importance of migration to ungulates, the loss or degradation of the existing migration routes on the BTNF would have strong negative implications for many wildlife species (Bolger et al. 2008).

Mapping migration routes is a powerful tool for designing informed policies that conserve and preserve important habitat (Sawyer et al. 2014). Here, we collate publicly available data on ungulate migration, land use patterns, land designations in order to map ungulate migration routes across western Wyoming and quantify their inter and intra species overlap to identify priority conservation areas. Then we provide a review of management strategies from forest plans within Wyoming, Idaho, and Montana; other agencies; and scientific literature. Ultimately, we use the findings of our analysis as well as the review to present management options and considerations for preserving ungulate migration on the BTNF. Identifying migration corridors, enacting responsible policies, removing movement barriers, and restoring previously used pathways will ensure a future for important and iconic ungulates in Wyoming.

In addition, we have created an online mapping tool in which users can explore all the datasets mentioned in this report in greater detail. This will resolve any limitations in the maps contained in this report. The mapping tool is available at the following link: https://gagecarto.github.io/btnfDataExplorer.

Migration Routes Overview

The following section details data collected from the recent Report on Ungulate Migrations of the Western U.S. (Kauffman et al. 2020). These data represent the most comprehensive collaboration among managers and biologist to map ungulate seasonal ranges and migration routes across Arizona, Idaho, Nevada, Utah, and Wyoming. This effort was largely spurred by Interior Secretary Order 3362, which served as a catalyst for the U.S. Department of the Interior (DOI) to work with Western states to enhance habitat quality for big game winter range migration routes (Secretary of the Interior 2018; for additional information, see link in References). The data generated by this effort are especially useful for land managers, non-governmental organizations (NGOs), and other stakeholders interested in learning more about migration routes and areas where conservation measures could benefit ungulates.

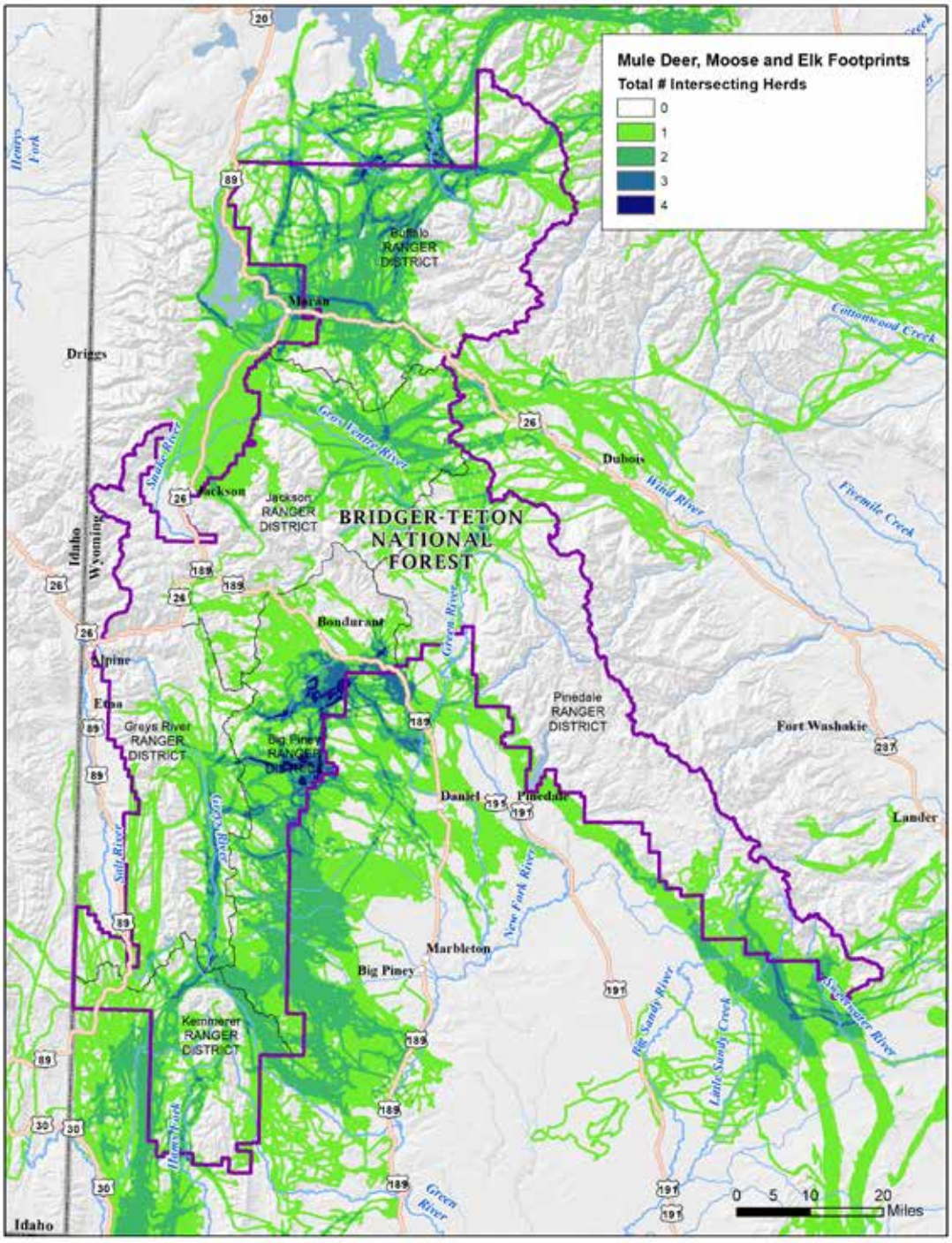


Figure 3: Intersecting migration footprints

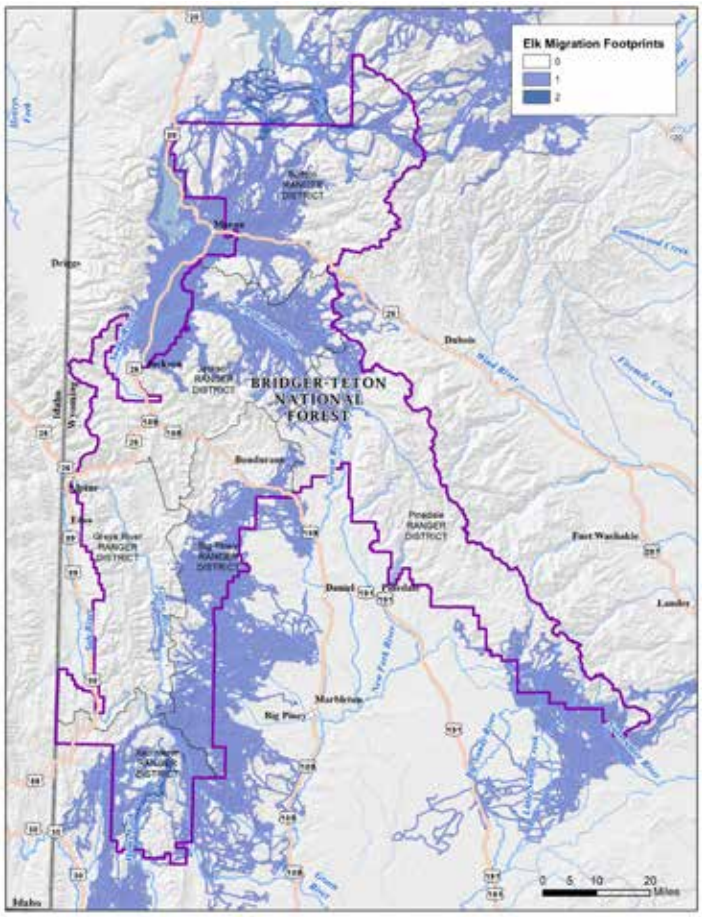
Data from the western migrations report are available for download as shapefiles suitable for analysis with a geographic information system (i.e. ESRI Shapefiles; Kauffman et al. 2020) for many different herds. In the areas surrounding the BTNF, there is migration route tracking data for 5 elk, 9 mule deer, and 2 moose herds (Figure 2). These data do not necessarily reflect all ungulate herds migrating on the BTNF; they are a sample from herds where GPS collars have been deployed and represent the best data available.

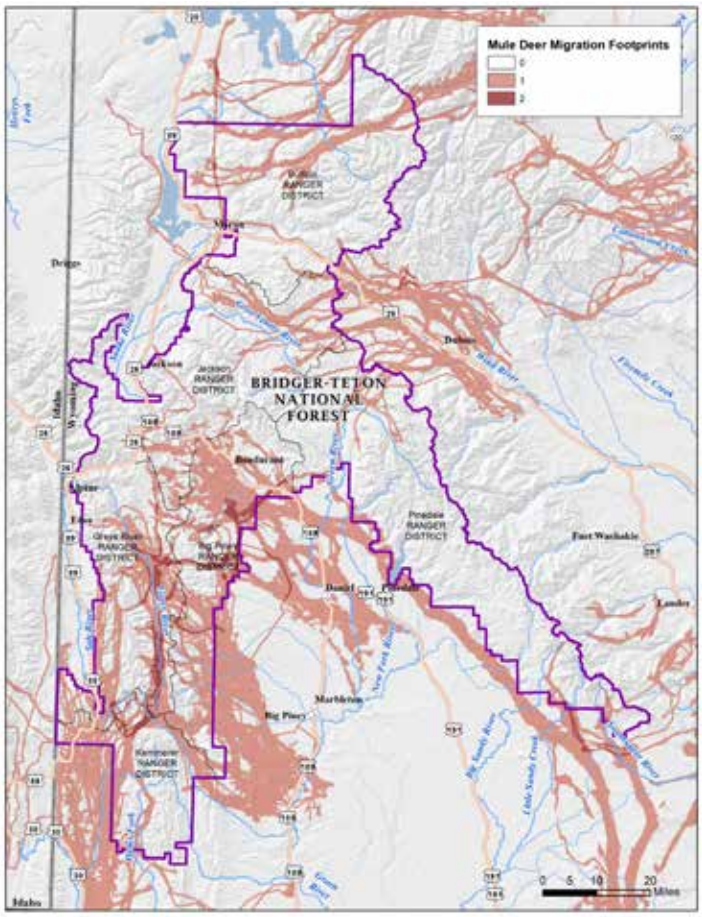
Each dataset represents the combined spring and fall migration paths of all those animals which were collared in a particular herd. The individual lines can be viewed as a standalone product or further analyzed using Brownian Bridge methods to identify population-level migration corridors with low, medium, and high use classifications (Kauffman et al. 2020).

To account for habitat conditions along the migration pathway as well as the surrounding region, we buffered individual migration lines by 300m to create migration polygons. The 300m buffer distance has been shown to provide similar corridors generated using Brownian Bridge methods and is commonly used as a simple alternative (H. Sawyer, personal communication 12/2020). Additionally, since not every animal in a herd can be collared, buffering the lines accounts for gaps in the migration footprint resulting from sampling.

In order to identify and tabulate areas of shared migration footprint, we intersected footprints across herds and species. This resulted in map layers which included a count of the total number of intersecting footprints (Figure 3). These maps were used to identify areas providing migration resources to multiple species and multiple herds. We also intersected footprints across each species, resulting in maps showing total number of shared footprints by species (Figure 4).

Given the available data, these analyses identify migration priority areas and highlight areas with high conservation importance for each species across the BTNF. The most obvious, and likely most important, area for mule deer is in the Big Piney Ranger District, just south of Bondurant, where many herds have overlapping migration routes. This area, near the Hoback River, has shared migration space for up to 4 herds including the state-designated Sublette Mule Deer migration route. Elk priority areas are near Jackson, where the Jackson elk herd moves between winter and summer range on the BTNF; along the Wyoming Range's eastern slope, where the Piney herd uses large areas for seasonal migration; and on the southern end of the Wyoming Range, where the Fossil Butte herd migrates near the Hams Fork River. Focusing efforts on preserving those locations and maintaining connectivity to those locations could provide high returns on conservation investments.





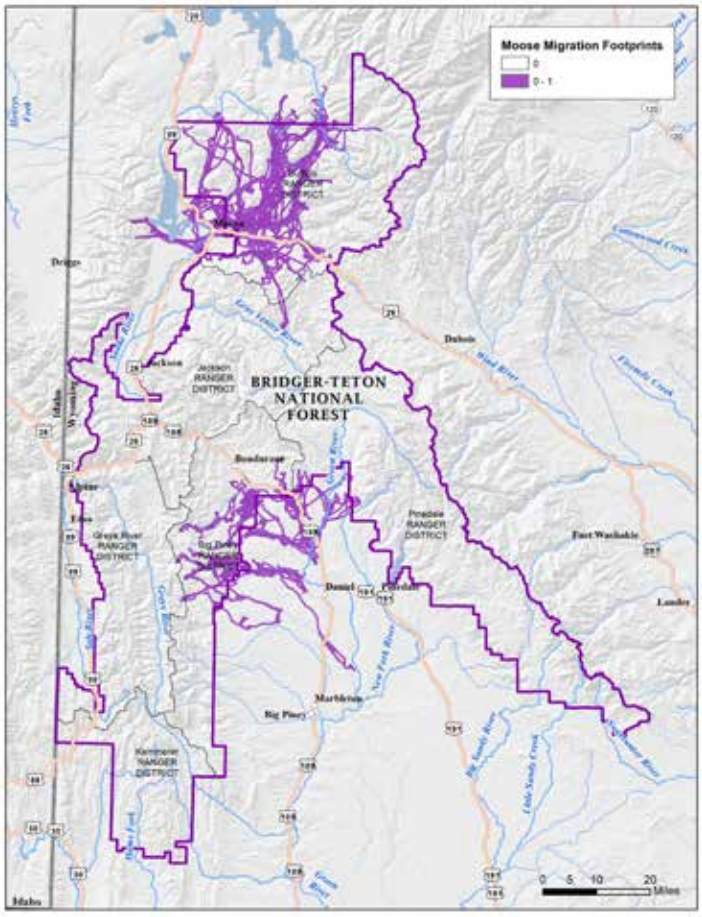


Figure 4 (a-c): Migration footprints by species

Corridor Designation Overview

In 2016, the Wyoming Game and Fish Commission approved the Migration Corridor Strategy, a process that identifies and designates big game migration routes (WGFD 2019). In 2020, the Wyoming Mule Deer and Antelope Migration Corridor Protection Executive Order was signed by Governor Mark Gordon, outlining a detailed and public process by which corridors may be designated to conserve habitat containing important resources for migrating ungulates (Gordon EO 2020-1). The multi-step procedure for designating corridors involves WGFD evaluation, public and stakeholder input, Game and Fish Commission approval, local area working group analysis, and the Governor's final approval. Designation under the Governor's Executive Order gives effective protections to the portions of corridors that occur on state-owned lands and where state permits are required. Private Landowners are encouraged to voluntarily work with WGFD to mitigate disturbances to migrating wildlife. Corridor status does not affect private property, only permits issued on state-owned lands can be denied and/or amended due to corridor designation. The State of Wyoming, as a stakeholder in federal land management decisions, can provide input on BLM leasing decisions, and the WGFD can submit comments when new leases are considered in state-designated corridors. It's important to note that with the amount of science and big game connectivity research that state fish and wildlife agencies are producing in the West, some of which has been directly funded by federal dollars through partnership initiatives such as Department of Interior Secretarial Order 3362, federal land managers have a strong opportunity and expectation to incorporate data-driven wildlife insights into federal land management decisions.

Mule Deer Scat, North Platte Valley, Colorado, Gregory Nickerson/Wyoming Migration Initiative, University of Wyoming

Sublette Mule Deer Corridor

In 2016, the Sublette Herd Corridor was the first ungulate migration corridor designated by the Wyoming Game and Fish Commission (Figure 5). The Sublette Herd supports an estimated 20,000 to 25,000 animals, and the corridor represents movements from three subpopulations, including the Ryegrass, Mesa, and Red Desert segments (Kauffman et al. 2020). Mule deer from the Ryegrass segment occupy winter ranges west of the Green River and migrate northwest into portions of the Wyoming Range, Salt River Range, and Hoback Basin. Mule deer from the Mesa segment occupy winter ranges east of the Green River and migrate northwest to summer ranges in the Wyoming Range, Snake River Range, Hoback Basin, and Gros Ventre Range. Mule deer in the Red Desert segment occupy winter ranges near Superior just north of I-80. These animals migrate nearly 150 mi (241 km) between seasonal ranges, along a narrow corridor that leads across the

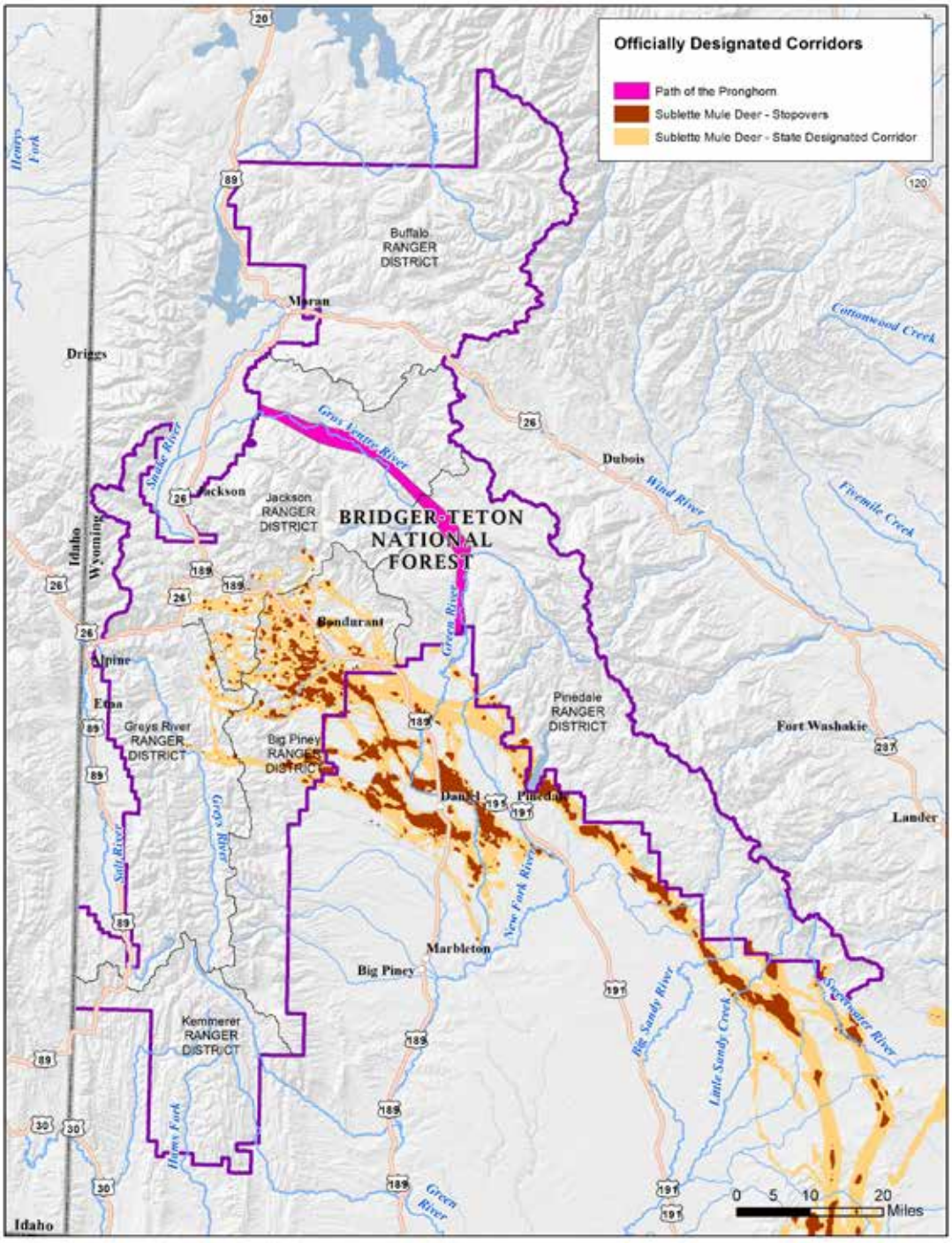


Figure 5: Officially designated corridors

Red Desert, along the base of the Wind River Range, and eventually into summer ranges around the Hoback Basin.

The Sublette mule deer migration corridor and its accompanying stopover areas intersect the BTNF in several locations—along the southwest edge of the Wind River Range, several small pockets of the BTNF are utilized as a migration corridor and stopover habitat; these include areas on the Sweetwater River, Little Sandy Creek, Big Sandy River and along Fremont Lake near Pinedale; near Bondurant, several areas provide important habitat for migration and stopover; and these areas intersect many other important migration footprints previously identified in this report and along the Hoback River.

Mule Deer Winter Range, Red Desert, Wyoming, Gregory Nickerson/Wyoming Migration Initiative, University of Wyoming

The Path of the Pronghorn

After intense hunting pressure in the 19th century, pronghorn had been hunted to near extinction and were no longer present around Jackson Hole. In the 1950s, pronghorn began to reappear in the valley spurring further study with collaring and tracking beginning in the 1980s. Studies indicated that pronghorn were migrating from winter range in the Green River Basin to summer range around Jackson Hole. Further detailed studies using GPS collars resulted in better delineation of the migration route termed the Path of the Pronghorn (Figure 5). In 2008, the Bridger-Teton National Forest amended its forest plan to protect the northernmost 45 miles of this migration corridor (Bridger Teton NF Plan Amendment 2008). The Forest Plan was amended to add the following standard: "all projects, activities, and infrastructure authorized in the designated Pronghorn Migration Corridor will be designed, timed and/or located to allow continued successful migration of the pronghorn that summer in Jackson Hole and winter in the Green River basin." This standard has successfully maintained the last remaining pronghorn migration to and from Grand Teton National Park. The amendment doesn't remove any protections already in place, it designates the corridor and adds the additional requirement that all uses must allow continued migration before they are authorized. Grazing operations in place at the time when the amendment was adopted are not affected because pronghorn migration was successfully happening in tandem with those activities. Conservation along this pathway has been accomplished within and beyond the BTNF through conservation easements, BLM Area of Critical Environmental Concern designation, and fence retrofitting. To date, it is one of very few federally-designated wildlife corridors in the U.S., underlining its significance (WCS 2021).

A herd of pronghorn along the highway south of Saratoga, Wyoming, Gregory Nickerson/ Wyoming Migration Initiative, University of Wyoming

Crucial Range Overview

Wyoming Game and Fish Department (WGFD) produced datasets on crucial ungulate range for several species including pronghorn, bighorn sheep, elk, mule deer, whitetail deer, and mountain goats. Crucial ranges are defined as any seasonal range or habitat (winter or yearlong) which has been documented as the determining factor in a population's ability to maintain itself at a certain level over the long-term. Population estimates come from WGFD and may be theoretical or derived from empirical data, such as long-term survey data or expert opinion (Tessmann 2007).

Crucial range data on the BTNF includes crucial winter and crucial winter/yearlong ranges. Crucial winter ranges are areas ungulates use primarily as winter range while winter/yearlong range can be used for both as annual or as winter range (WGFD 2015). While the timing of weather conditions vary across the state and between years, the winter period is commonly between December 1st and April 30th. During the winter months, there is a significant influx of additional animals into crucial winter range from other seasonal ranges.

Pronghorn movement data show distinct crucial winter/yearlong ranges near Dubois and in the Green River Basin; there were no data that suggested crucial ranges occur on the BTNF (Figure 6a).

Elk data, on the other hand, highlight several areas of crucial winter and winter/yearlong range across the BTNF (Figure 6b). Near Moran and Jackson, several large areas were identified as crucial winter range adjacent to the National Elk Refuge. Along the southwestern flank of the Wind River Range, one small area of winter range intersected the BTNF just to the north of Pinedale. Elk crucial winter/yearlong ranges also occurred south of Jackson along the Snake River, south of Bondurant along the Hoback River, south and east of Alpine along the Salt and Greys Rivers, and on the southern end of the Wyoming Range (Figure 6b).

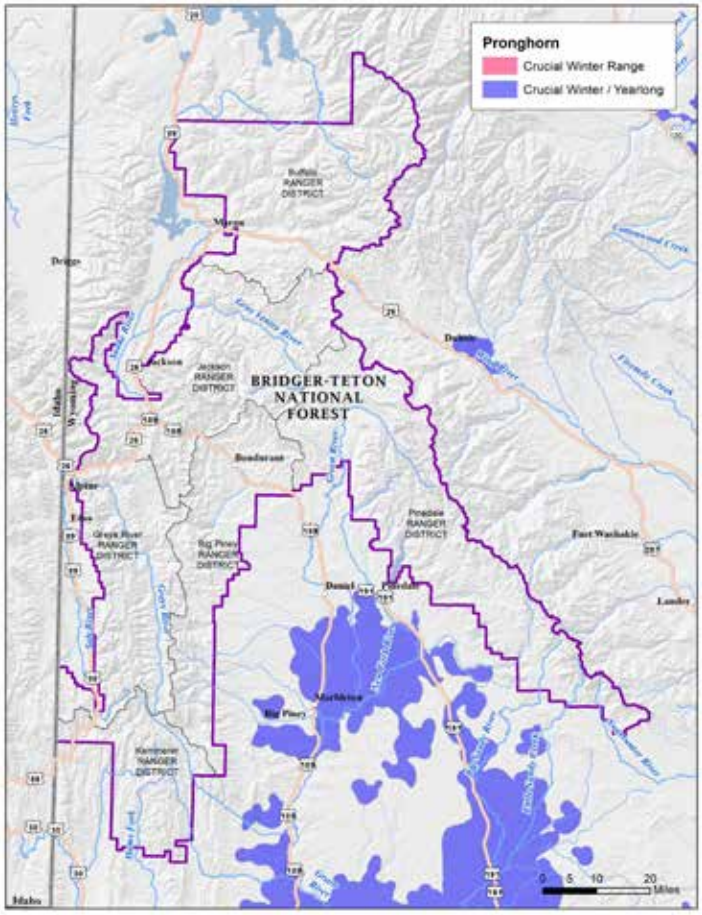
Similarly for mule deer, many areas of crucial range were present on the BTNF (Figure 6c). Some of the crucial winter range areas occurred along the southwest flank of the Wind River Range. Small patches of crucial winter and winter/yearlong range occurred near Jackson and south of Etna.

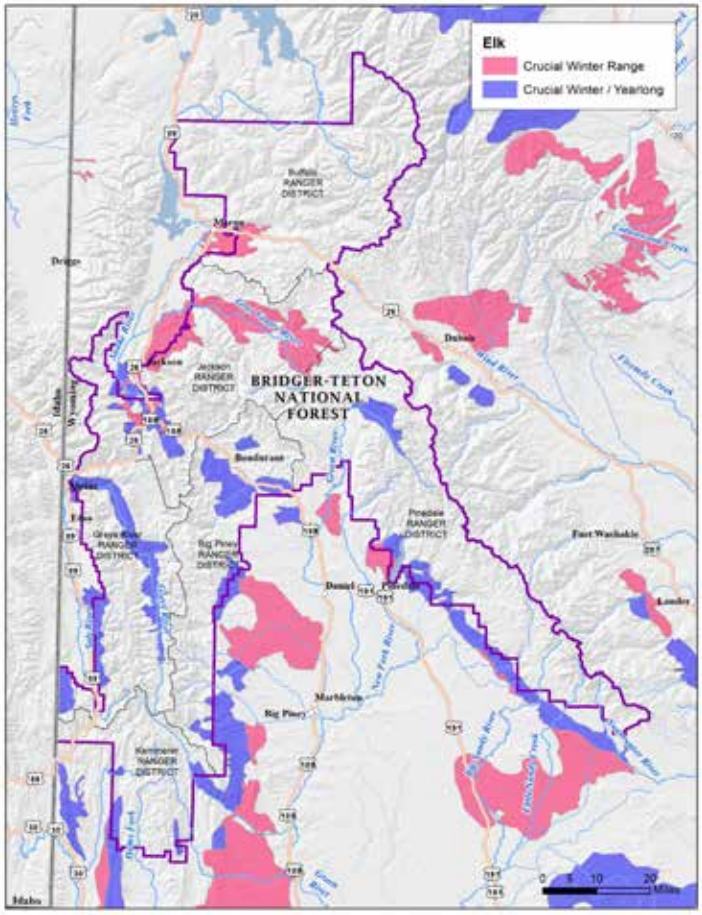
The analysis classified one small area of crucial winter/yearlong crucial for mountain goat just east of Alpine (Figure 7a).

Many areas of the BTNF were identified as crucial habitat for moose (Figure 7b). One small area of crucial winter range was mapped south of Moran. Areas of crucial winter/yearlong range were mapped throughout the forest with large areas south of Bondurant, along the upper Snake River, west of Etna on the Greys River and north of Daniel along the Green River. Many other areas of crucial winter/yearlong moose range were identified along river corridors across the BTNF.

There were many patches of crucial range for bighorn sheep identified in the BTNF (Figure 7c). These areas included winter range to the northeast of Jackson and northwest of Bondurant. Several pockets of crucial winter/yearlong range occurred above the upper Green River and to the north of Bondurant.

Similar to mapping migration footprints across species to identify high use, and therefore high priority areas, we stacked crucial range areas across species to determine similarly important areas (Figure 8). Again, the higher the total crucial ranges, the greater the number of species utilizing that location and greater the potential conservation value.





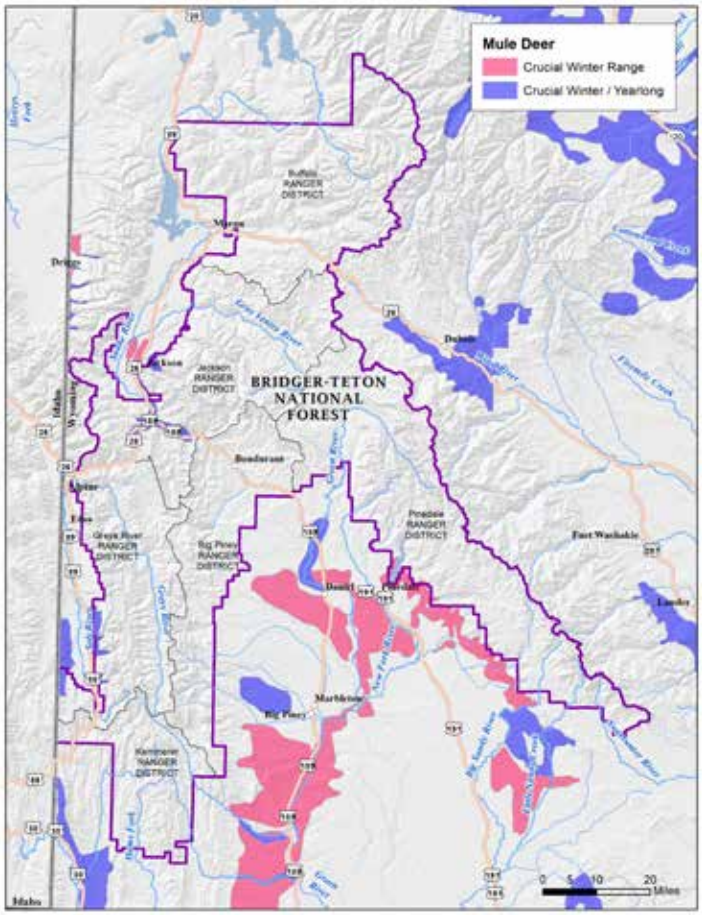
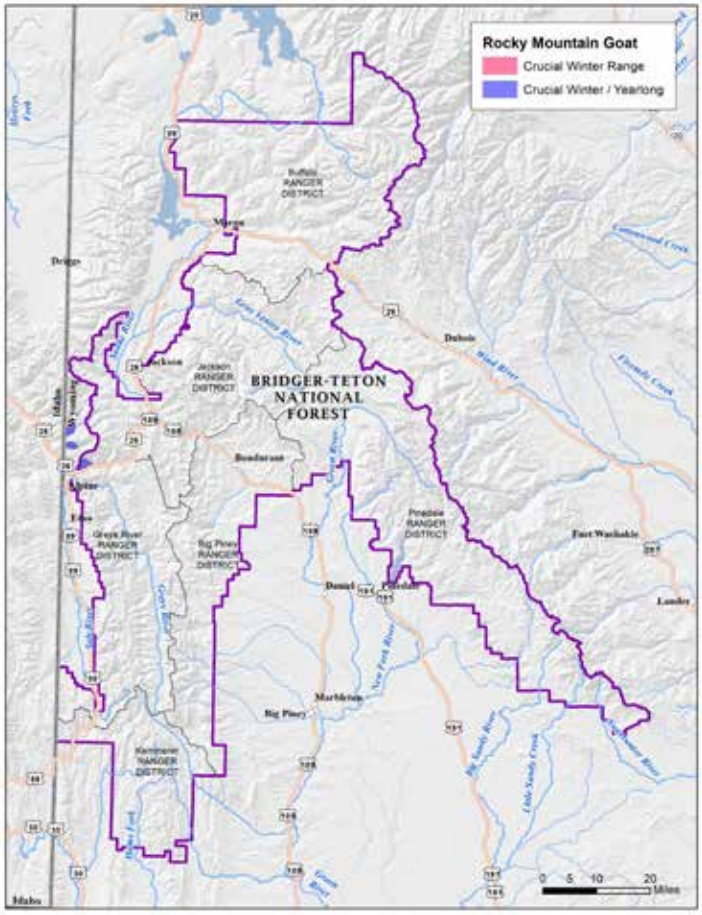
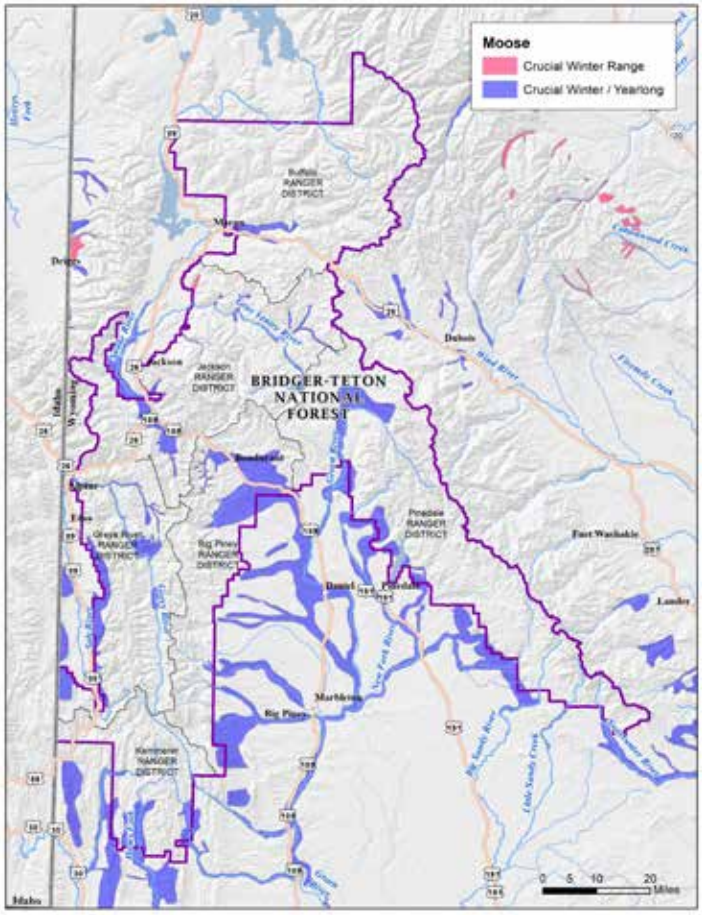


Figure 6 (a-c): Crucial ranges by species





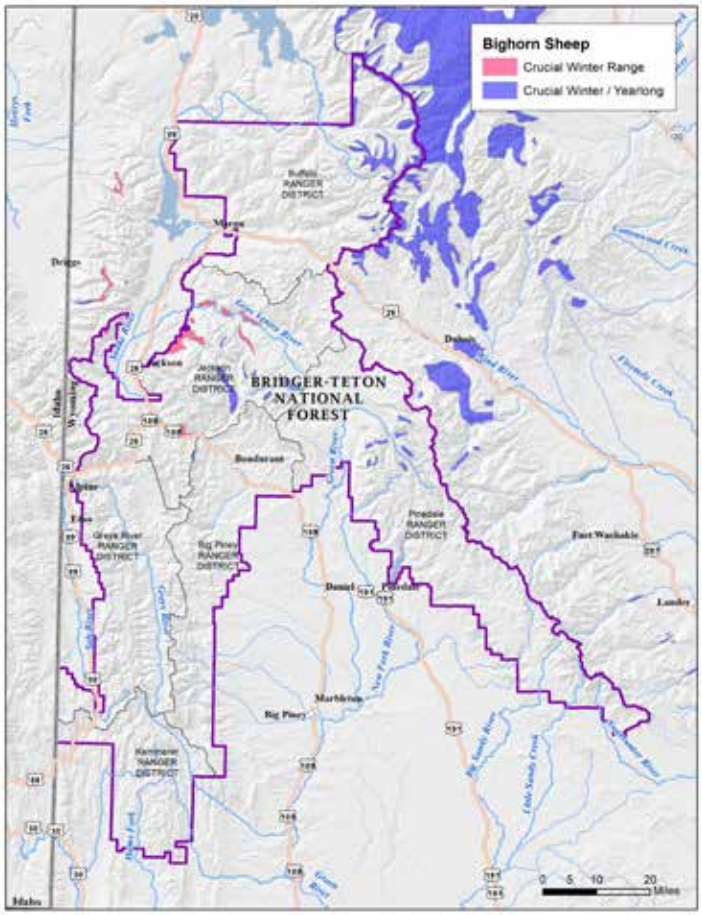


Figure 7 (a-c): Crucial ranges by species

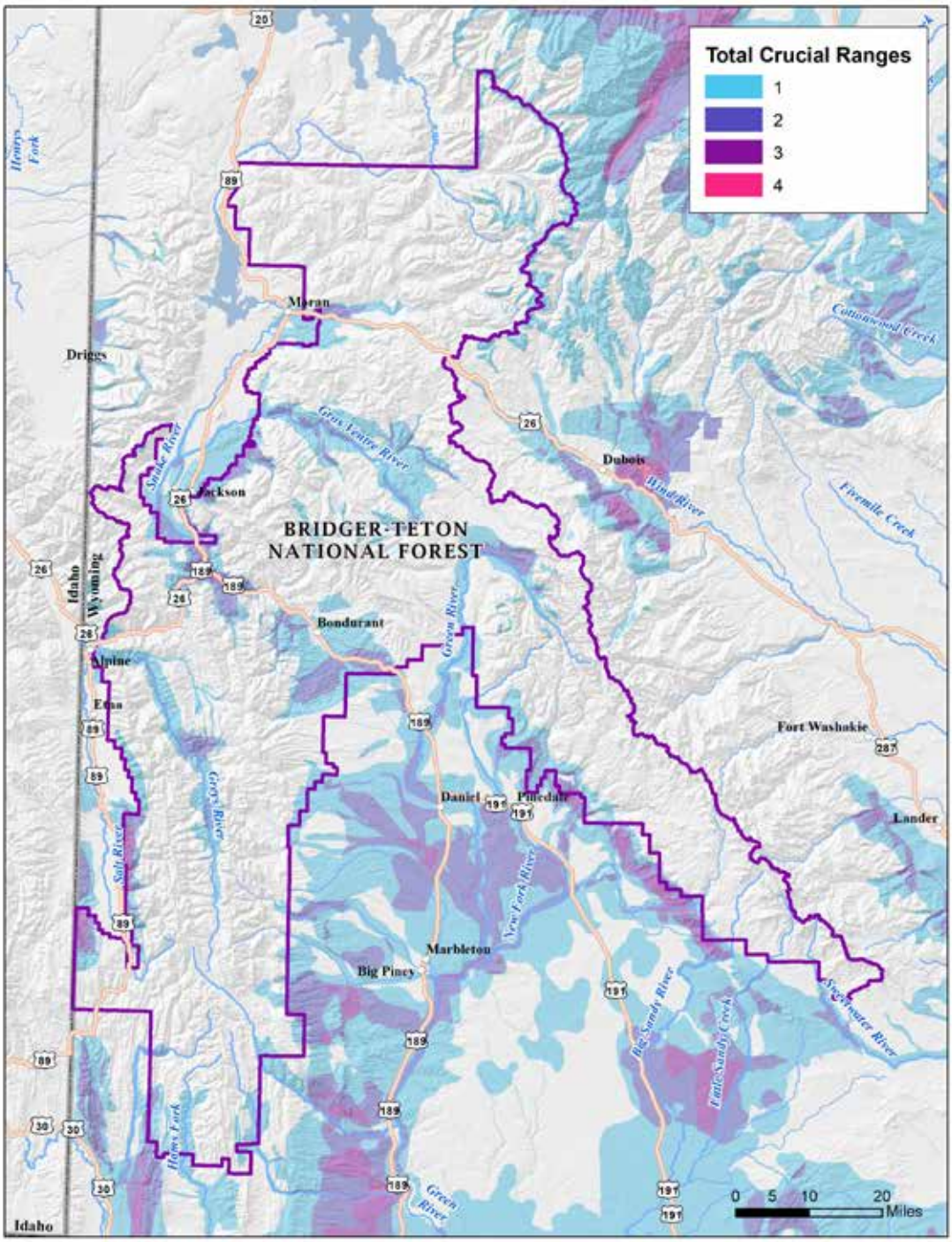


Figure 8: Intersecting crucial ranges

Forest Uses Data Overview

Ungulates encounter many anthropogenic and natural hazards as they migrate between seasonal ranges. In addition to predation, disease, and harsh natural conditions, there is a growing number of human-derived disturbances, such as roads, trails, oversnow travel (i.e. snowmobiles), timber harvest, energy development, and livestock grazing. In this report, we utilized many different datasets to capture potential hinderances to big game migration. Here we explore migration impediments that may take the form of impermeable or semi-permeable obstacles that block an animal's path, as well as obstacles that alter finely-tuned migration behaviors, decoupling animal movements with important ephemeral resources. There are also additional factors that may impact migration, such as climate change, that are beyond the scope of this report.

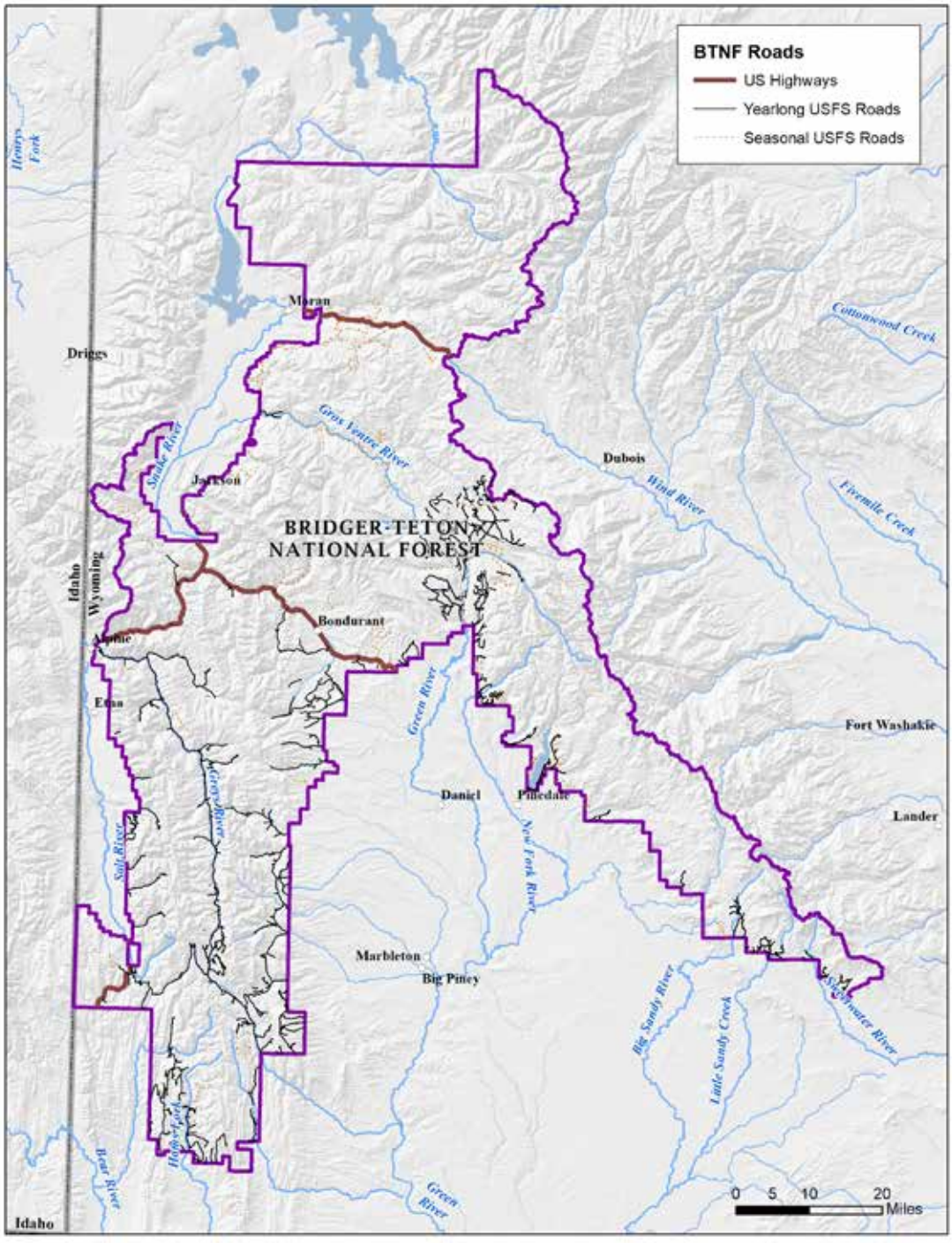


Figure 9: BTNF road map

Roads

Roads present challenges to migrating ungulates, both directly, such as mortality from vehicle collisions or as an impermeable or semi-permeable barrier, and indirectly, such as increasing human activity (Huijser et al. 2008, Spitz et al. 2019, Kauffman et al. 2020). The BTNF contains 1,652 miles of roads (Figure 9) within its borders, and the current forest plan intends to support building more. We classified all existing roads into three groupings: primary US highways, forest service roads open all year, and seasonal forest service roads. Each category has detailed metadata, such as information about seasonal closures, which can be further explored in the web map associated with this project (available here: https://gagecarto.github.io/btnfDataExplorer/).

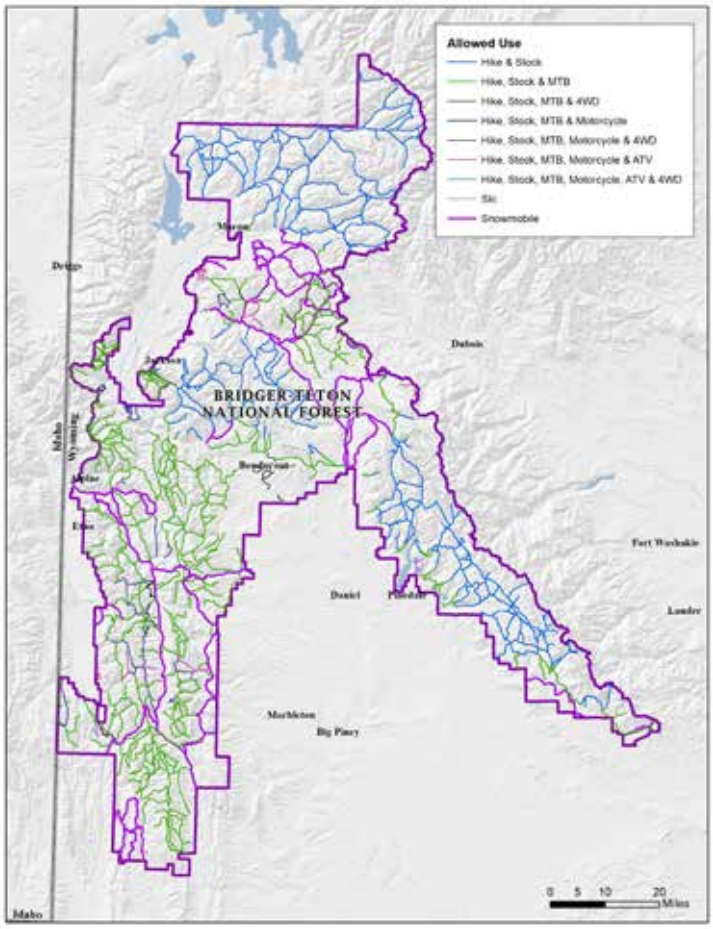
Most of the roadways were considered yearlong USFS roads, followed by seasonal roads, and then US highways (Table 1). Many of the year-long roads on the BTNF were concentrated along the upper Green River, the west slope of the Wind River Range and throughout the Wyoming Range. Many of the year-long roads might be impassable during winter months but do not have an official closure date.

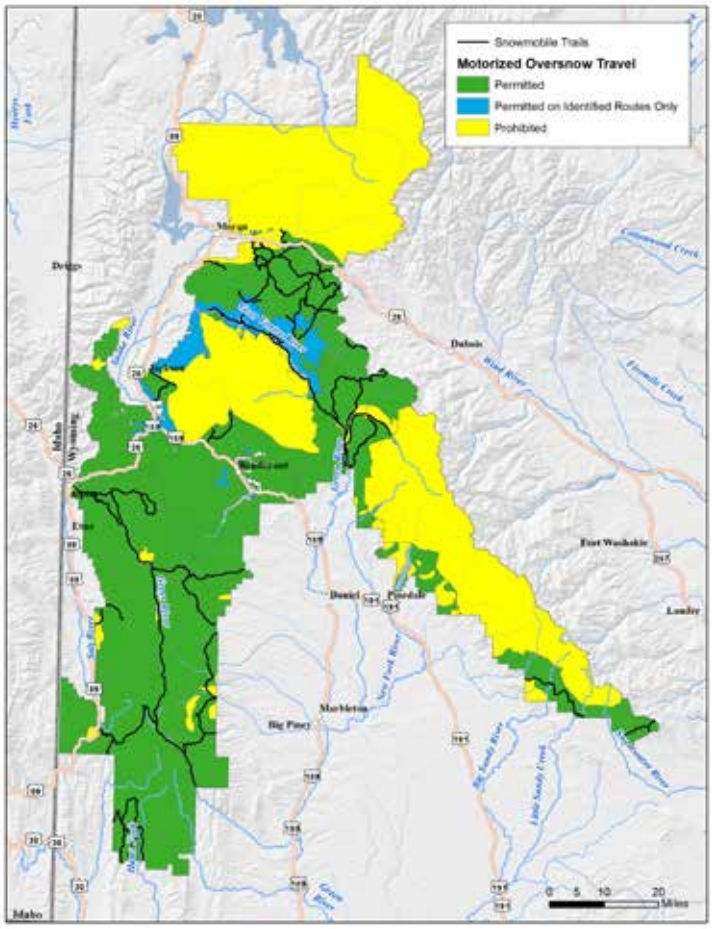
Trails

Trails in and of themselves may not directly hinder big game migration, but they do facilitate potential disturbances by increasing access for recreationalists, domestic animals, and natural predators. Recent research demonstrates that elk, bighorn sheep, and mule deer avoid human activity associated with trails (Papouchis et al. 2001, Rogala et al. 2011, Spitz et al. 2019). Avoiding trails and other behavioral responses result in a relatively cryptic and insidious form of habitat loss and fragmentation. We obtained data for all trails and associated metadata describing the activities permitted on each trail on the BTNF from the national USFS data clearinghouse (Figures 10 & 11; Table 1). Allowed uses included stock animals, hiking, mountain biking, motorcycles, ATVs, 4wd vehicles,

Figure 10 (left) : BTNF trails

Figure 11 (right) : BTNF winter motorized use map





ROAD TYPE	MILES	PERCENT TOTAL
Primary Highway	123	7%
Yearlong USFS	1034	63%
Seasonal USFS	495	30%

ALLOWED USE	MILES	PERCENT TOTAL
Hike & Stock	1047	31%
Hike, Stock & MTB	1483	43%
Hike, Stock, MTB & 4WD	42	1%
Hike, Stock, MTB & Motorcycle	125	4%
Hike, Stock, MTB, Motorcycle & 4WD	5	0%
Hike, Stock, MTB, Motorcycle & ATV	83	2%
Hike, Stock, MTB, Motorcyle, ATV & 4WD	6	0%
Ski	38	1%
Snowmobile	587	17%

MOTORIZED OVERSNOW	MILES	PERCENT TOTAL
OPEN	2991	56%
CLOSED	2200	41%
OPEN ON ROUTES ONLY	184	3%

Table 1: Roads, trails and winter motorized tabular summary

and two winter classes including snowmobiles and skiers (Figures 10 & 11). These trails are shown in Figure 10, color coded by allowed use, however, the data are difficult to discern at the forest scale and are more easily explored using the companion web map for this project (https://gagecarto.github.io/btnfDataExplorer/).

Oversnow Motorized Travel

Snowmobile traffic can disturb ungulates, potentially displacing them to poor habitats, thereby increasing their energetic demands during a time when they are already resource limited (Harris et al. 2014). The BTNF maintains data on areas open to snowmobile travel, which can be classified as open, closed, or open on designated trails only (Figure 11). In addition to areas open to cross country snowmobiling, there are 587 miles of designated snowmobile trails on the forest (Figure 11 ; Table 1).

Timber Harvest

Strategic timber harvest planning can be utilized as a tool to balance human enterprise with ungulate habitat requirements. Stand age, species composition, larger spatial properties, and road access will determine whether logging activities are compatible with providing the forage, escape habitat, and thermal cover that ungulates need to survive.

Figure 12 shows timber stands on the forest that could be considered for harvest. This information comes from a study of timber characteristics such as stand age, health and recent fires (Data provided by BTNF Resource Information Manager, 11/2020). Using the interactive map viewer (available here: https://gagecarto.github.io/btnfDataExplorer/), users can further explore and click on individual stands to retrieve tree type and other information.

This current map is an update on the 2012 maps and accounts for changes due to wildfires, harvests, and prescribed burns occurring between the years 2013 and 2017. Large wildfire updates were addressed using burn severity data from the post-fire monitoring programs: Monitoring Trends in Burn Severity and Rapid Assessment of Vegetation Condition after Wildfire.

Grazing Allotments

As with timber harvest management, prudent ranching can simultaneously support the livestock industry and migrating ungulates. Livestock and big game transmit diseases to one another, compete for forage, and fences erected to contain livestock can also impede migration pathways. However, livestock may also benefit big game, such as when supplemental feed for livestock provides helpful resources for ungulates, or grazing is used to improve big game habitat (Chaikina et al. 2006, Mosley and Brewer 2006). We accounted for livestock use by including spatial data for grazing allotments, collected from a national dataset and clipped to the BTNF (USFS – Geospatial Data Discovery 2020; Figure 13). Allotments on the BTNF are classified into three groups: active, which

are used for grazing; closed, which are no longer used for grazing; and vacant, which is not currently grazed but still has the potential for being assigned to a new permittee.

Energy Development

Ungulates often avoid oil and gas development when it occurs within their migration corridors, responding by speeding through areas, spending less time at stopover sites, or detouring around energy development areas during migration (Sawyer et al. 2013, Middleton et al. 2018). The majority of leased areas occur outside USFS lands, however, much of the energy development in and around the BTNF is concentrated in the Green River Basin (Figure 14). Nonetheless, there are a number of leases on the BTNF including groupings west and northwest of Big Piney and another to the northwest of Bondurant. Previously, there were many other leases which were retired as part of the Wyoming Range Legacy Act.

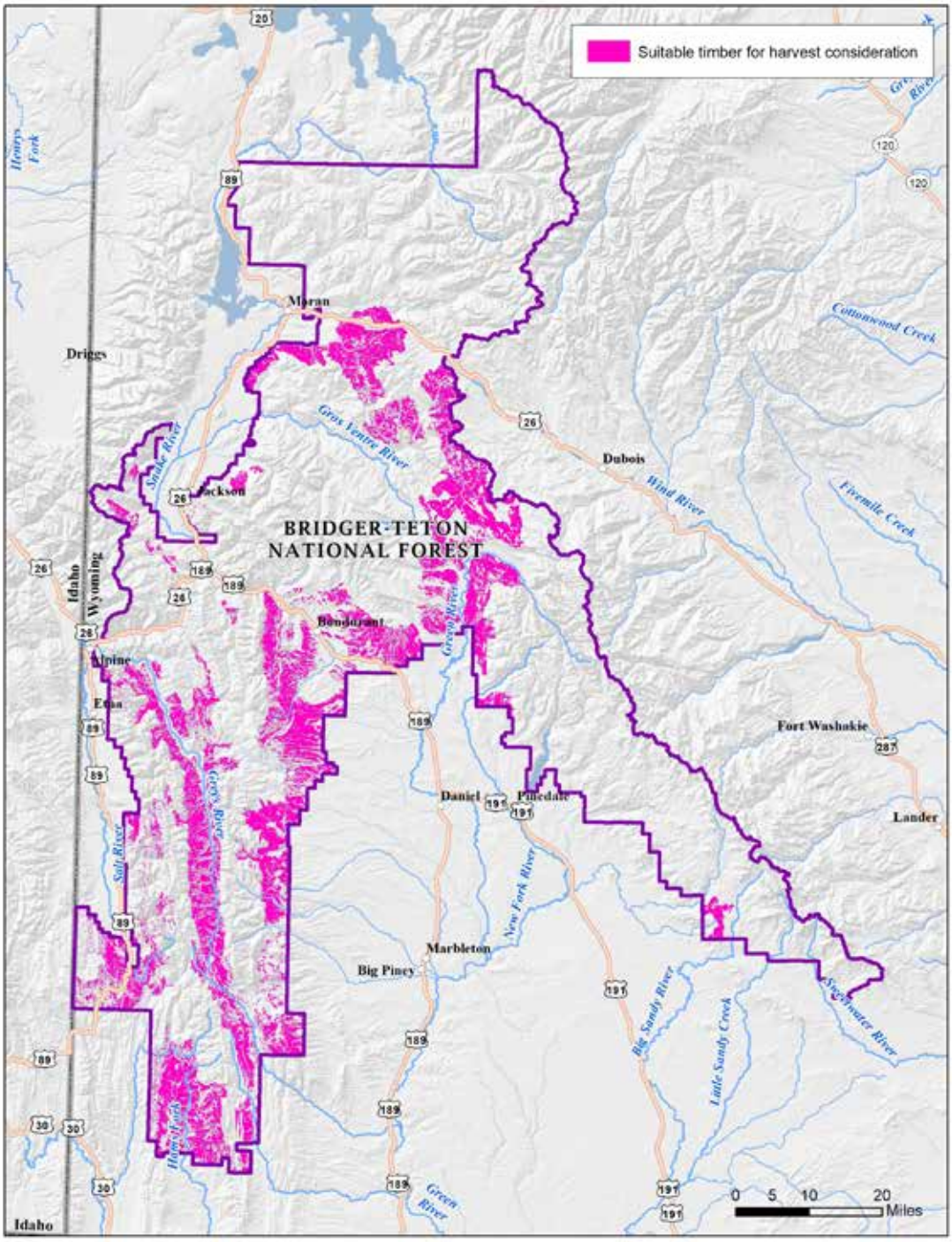


Figure 12: Timber suitable for harvest

Very few producing wells exist on the forest. Recent data show 7 flowing wells, one classified as an active injector, and another that is temporarily abandoned.

In addition to evaluating issues caused by current energy development, it is important to look ahead to examine and address additional hinderances that may arise. We used results from BLM studies known as reasonable future development scenarios to map future energy development. These datasets are produced for individual field offices and were compiled by Alison Gallensky of Rocky Mountain Wild (personal communication 11/10/2020). These studies look at underlying geology, lease restrictions and overall feasibility of development. There are some interesting patterns in energy development potential. Just east of Bondurant, there is an area classified as having medium/moderate probability for future development. In addition, there are small pockets of low and very low probability along the southwestern edge of the Wind River Range, across the Gros

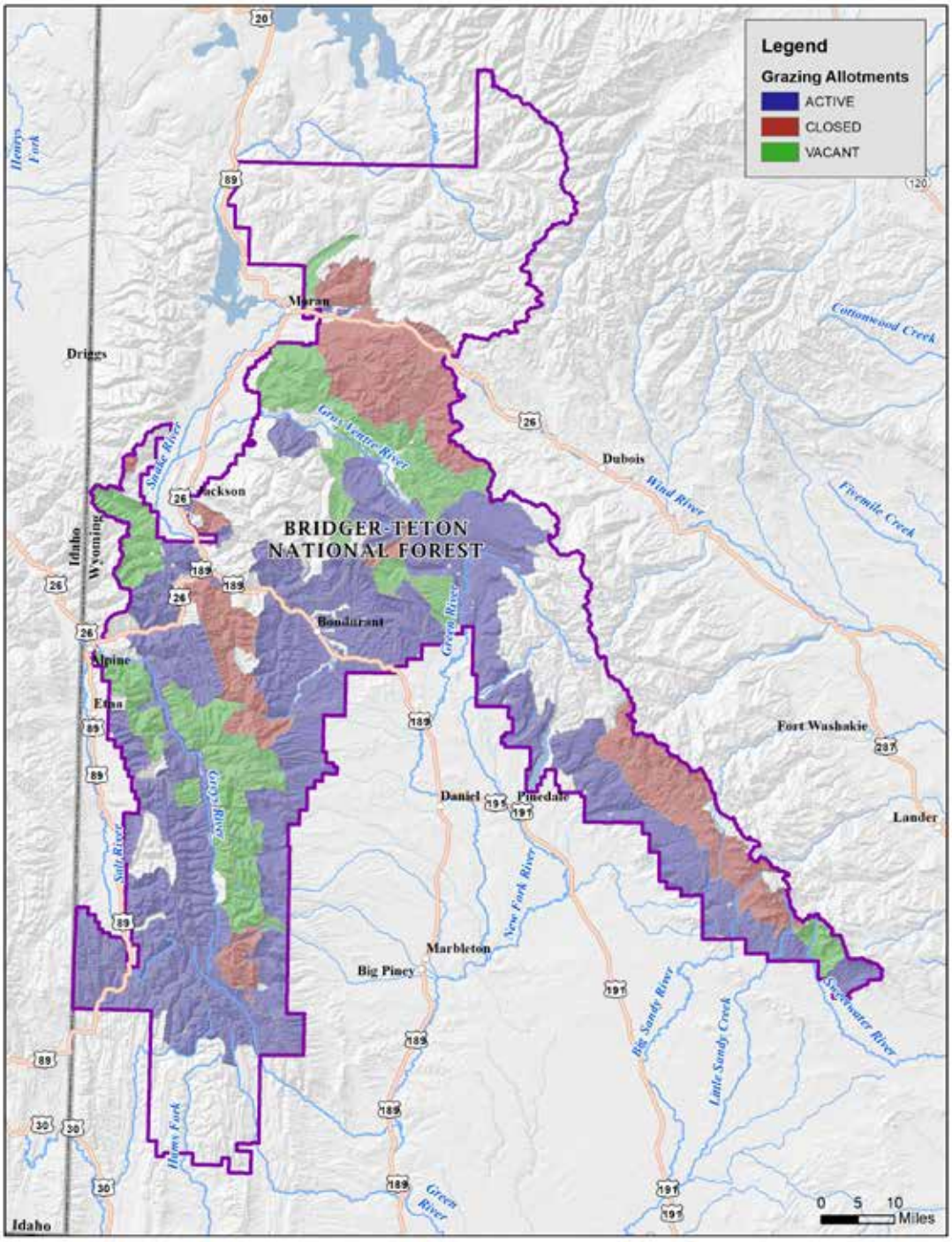


Figure 13: Grazing allotments on the BTNF

Ventre range and around Jackson. Looking at the future of migration habitat, much of the forest is classified as not available (NA), meaning development is not possible as a result of permanent energy withdrawals or other management designations.

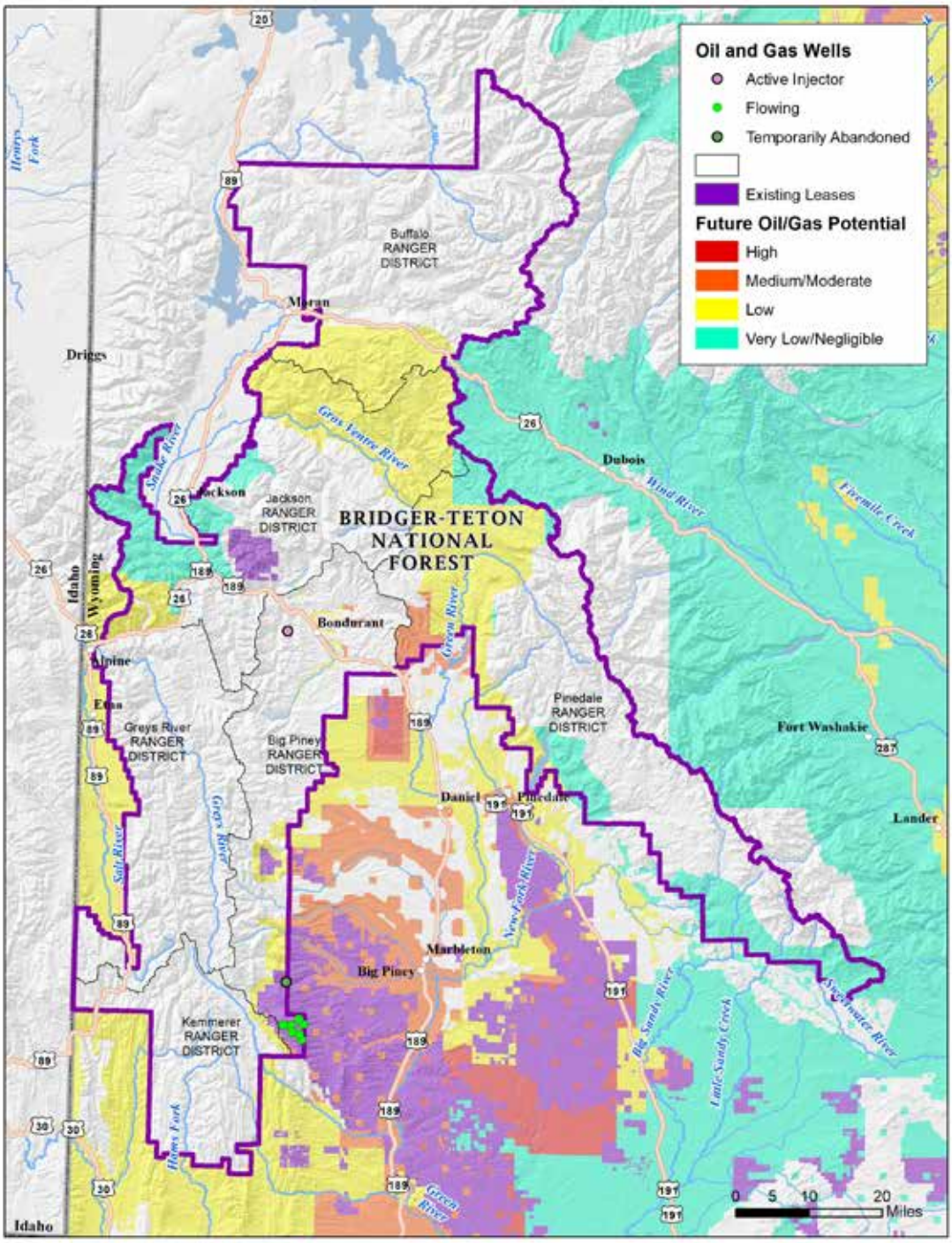


Figure 14: BTNF energy development and potential

BTNF Land Designations & Protections

Using data from the Protected Areas Database of the United States (PAD-US; USGS GAP 2020), we mapped land management allocations and protected statuses on the BTNF (Figure 15 & 16). The PADUS project has classified public lands into 4 categories of protected statuses: 1) permanently protected with natural disturbances not suppressed, 2) permanently protected with natural disturbances sometimes suppressed, 3) no permanent protections, and 4) unknown status (Figure 16).

A large portion, 38% of the forest is permanently protected with GAP 1 status (Figure 16; Table 2). These areas are mainly Wilderness Areas having no suppression on natural disturbances, meaning that naturally occurring fires would not be managed. There is another 5% of the forest in the alternative, GAP 2 permanent protection, these being the

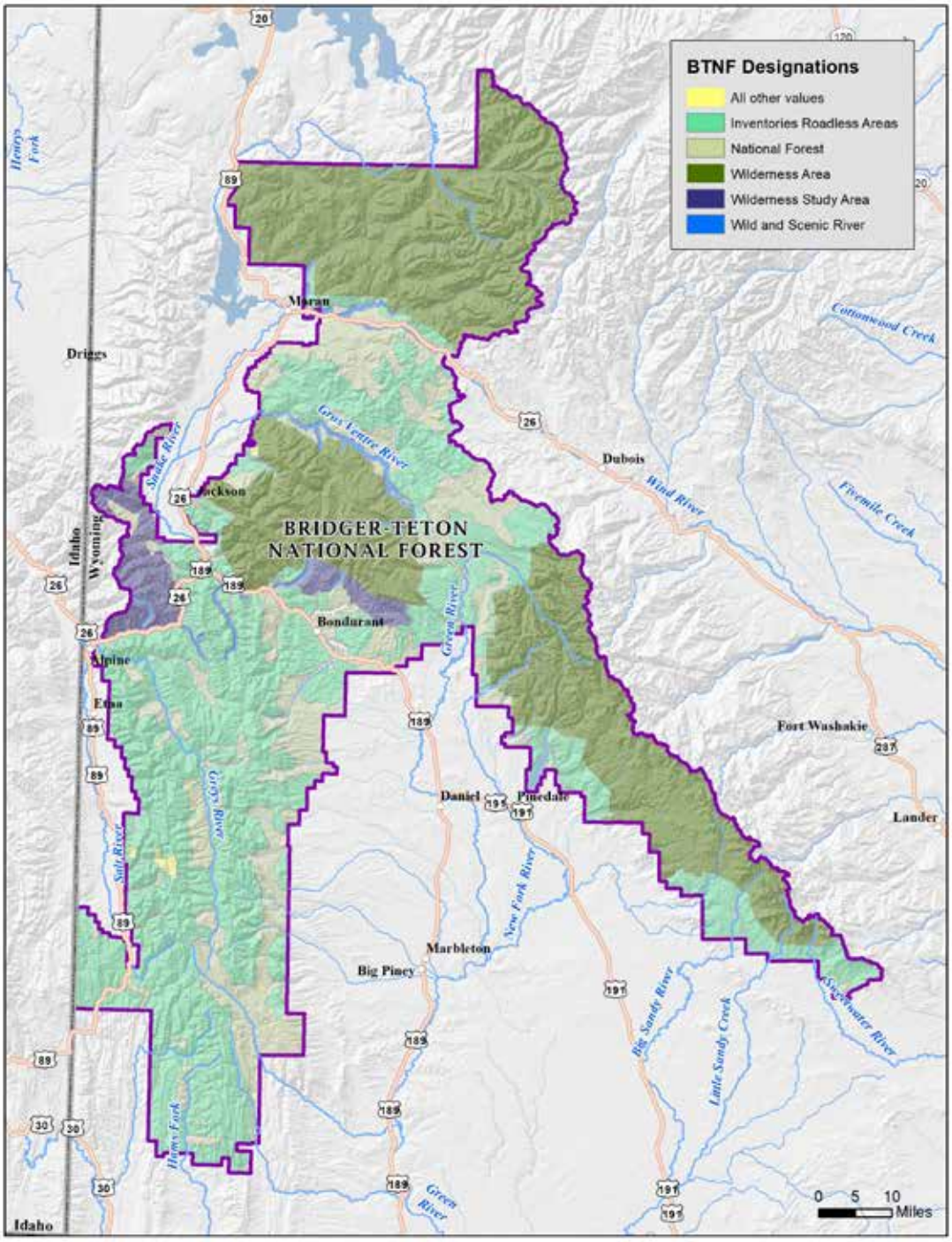


Figure 15: BTNF land designations

Wilderness Study Areas and Wild and Scenic Rivers. The remaining 57% of the Forest has a classification of being unprotected and is made up of inventoried roadless areas (41%) and general forest service lands (16%). Ungulates migrating on the BTNF vary in the degree to which their migration routes and crucial ranges fall in protected habitat, ranging from zero (for moose crucial winter range) to 99 percent (for bighorn sheep and mountain goat crucial winter/yearlong range; Figures 17 & 18).

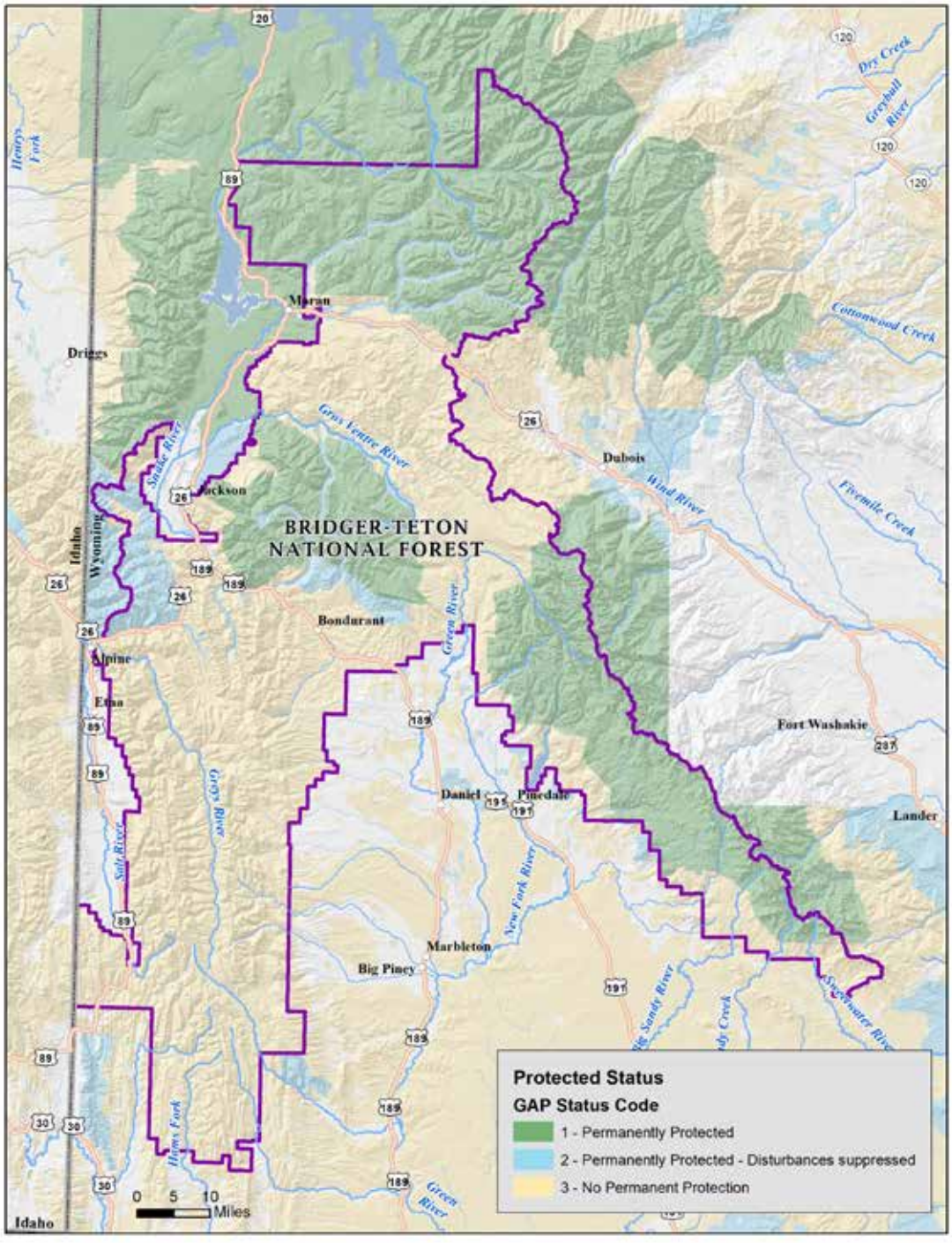


Figure 16: BTNF GAP protected status

GAP STATUS	MILES	PERCENT TOTAL
1	2027	38%
2	263	5%
3	3085	57%

DESIGNATION	MILES	PERCENT TOTAL
Inventoried Roadless Area	2200	41%
Wilderness Area	2026	38%
National Forest	878	16%
Wilderness Study Area	175	3%
Wild and Scenic River	82	2%
Resource Natural Area	8	0.14%
State Resource Management Area	4	0.08%
State Conservation Area	3	0.05%
Conservation Easement	2	0.04%
Ranch Easement	1	0.03%
Other Easement	1	0.02%

Table 2: Designation and protected status tabular summary

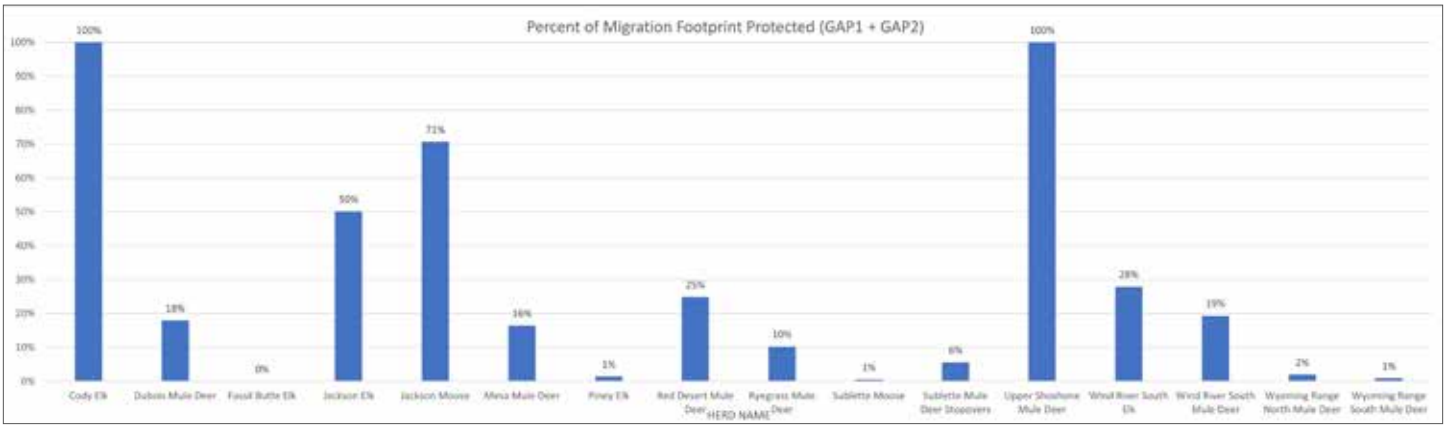


Figure 17: Footprints area protected summary

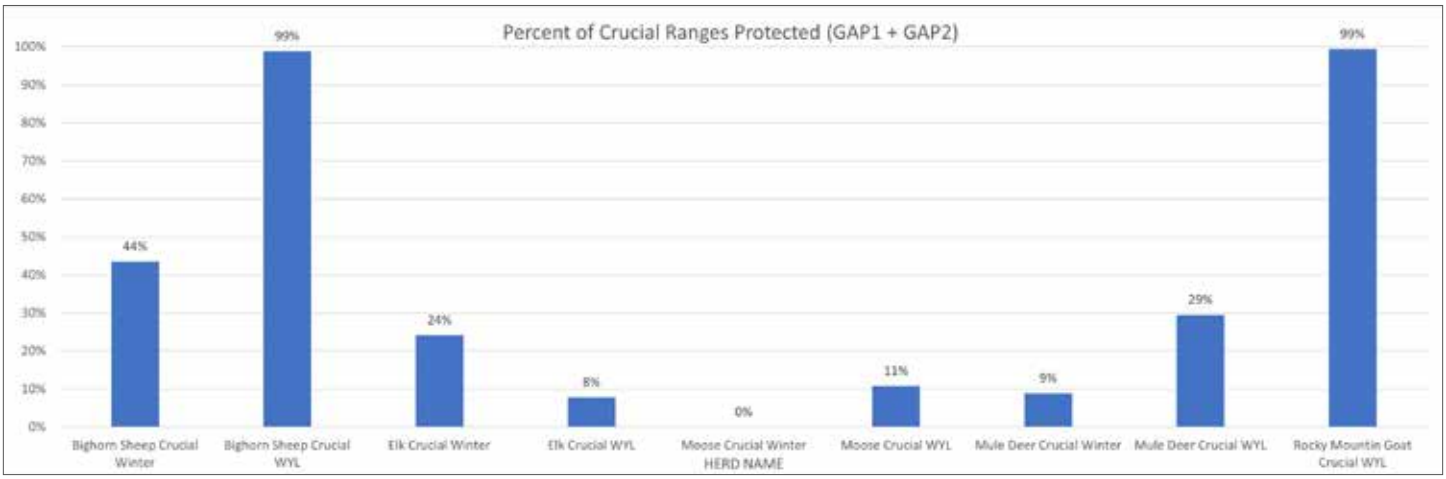


Figure 18: Crucial ranges protected summary

Potential Migration Facilitation Strategies

Department of the Interior and Wyoming

As the agency tasked with managing large areas of land held in the public trust, the Forest Service has the opportunity to enact management that will have a significant footprint. Practices developed by other agencies, such as the Department of the Interior, can provide guidance for the BTNF to consider. In 2018, the DOI issued Secretarial Order 3362 designed to improve habitat quality for Western big game winter range and migration corridors. In this Secretarial Order, there are several practices the BTNF could borrow to improve conditions for migrating ungulates. The DOI advocates restoring degraded winter range and migration corridors by removing encroaching trees from sagebrush ecosystems, rehabilitating areas damaged by fire, and restoring invasive vegetation to improve the habitat value for big game. Further, the DOI recommends working cooperatively with private landowners and state highway departments to promote wildlife-friendly fencing. This includes identifying areas where fences are impeding migration and retrofitting those fences with smooth wire, removing extraneous fencing, or seasonally adapting fencing (e.g. lay-down fencing) in important movement corridors.

The Executive Order 2020-1 Wyoming Mule Deer and Antelope Migration Corridor Protection provides guidance for public lands in Wyoming regarding mule deer and pronghorn antelope migration corridors. The Forest Service could apply similar approaches as in the Executive Order and Path of the Pronghorn to replicate those successes in other locations.

Strategies from Forest Plans and Scientific Literature

Starting from a broad level, identifying high priority conservation areas allows managers to focus on locations with elevated conservation value. Among the top habitat types to protect are stopover habitat sites, crucial ranges, birthing grounds, areas utilized by multiple herds and/or species, travel bottlenecks, and other areas where sensitive behaviors occur. These areas are used year after year, so identifying these areas and preserving them will provide a lasting benefit. If important habitat falls on public land, and the Forest Service needs to facilitate access around sensitive sites, voluntary road and trail easements can be purchased on private land that allows the public to bypass sensitive areas. In addition, the BTNF can identify land adjustments and rights-of-way on the Forest to improve management, public access, and/or wildlife connectivity annually.

In places where priority areas are not yet protected, the BTNF could work with local land trusts to establish conservation easements or habitat leasing. Land trusts in the Greater Yellowstone Area are currently working to secure conservation easements on large portions of private ranches within identified migration corridors, and could provide natural partnerships in this endeavor (Kauffman et al. 2020). Habitat leasing is in early stages of development in Wyoming, but has real potential for purchasing a lease in a migration corridor to incentivize landowners and their contribution to corridor habitat. A habitat lease would protect the migration corridor from habitat fragmentation and prioritize habitat improvement projects for those private landowners living within the designated migration corridor.

In addition, the BTNF can work beyond its usual reach by collaborating with other agencies and/or across jurisdictional boundaries to create policies that support migration. For example, the Helena-Lewis and Clark National Forest Plan calls for management of habitat for native ungulates to be consistent with management of similar habitat on adjoining state or federal land (Helena-Lewis and Clark NF Plan 2020). In this plan, the Elkhorns Wildlife Management Unit was designated, encompassing portions of the Helena-Lewis and Clark National Forest and the Beaverhead-Deerlodge National Forest. This collaborative effort is composed of federal, state, and local citizens (Helena-Lewis and Clark NF Plan

2020). The Boise River Wildlife Linkage Partnership (BRWLP) provides another example of multi-group collaborations. This partnership is working to conserve and create effective wildlife crossings and other mitigation enhancements through the Warm Springs Avenue and State Highway 21 corridor to maintain habitat connectivity and reduce wildlife-vehicle collisions. Partnering organizations include Idaho Department of Fish and Game, Idaho Transportation Department, Boise County, Ada County Highway District, Ada County Parks and Waterways, Rocky Mountain Elk Foundation, the City of Boise, the Boise National Forest, and members of the public (Boise NF Plan 2010).

Roads, Trails, and Oversnow Travel

Many forest plans throughout Idaho, Montana, and Wyoming suggest avoiding constructing new trails, where possible. When new infrastructure is necessary, conserving ungulate migration requires that forest managers take migration routes, stopover locations, and other important habitat features into consideration. In addition, timing restrictions can be placed on road-building activities and road use to avoid disturbing or displacing wildlife (Helena-Lewis and Clark NF Plan 2020). These are principles that the BTNF currently addresses in their forest plan, in addition to using buffer areas around potentially disruptive infrastructure. For example, the BTNF calls for creating low human use zones containing security areas in locations adjacent to concentrated human activity (Bridger-Teton NF Plan 2015). Zone size should depend on the ungulate species and type of human use typical for a particular area. For instance, elk respond strongly to ATVs (fleeing 1350m), followed by cyclists (fleeing 750m), then equestrians (fleeing 550m), and least strongly to hikers (fleeing 400m; Wisdom et al. 2004, Wisdom et al. 2018, BHA 2021). Mule deer, on the other hand, did not respond as strongly, possibly responding to an off-road activity by seeking dense cover rather than fleeing. For either species, retreating from recreationalists could result in increased movements, reduced foraging opportunities, and a subsequent reduction in opportunities to gain fat reserves for winter survival.

Another policy BTNF already has in place is regulating non-motorized and motorized vehicle access seasonally or year-round to protect sensitive big game habitats, such as primary feeding areas, crucial winter range, calving/fawning/lambing and rearing areas, rutting complexes, and migration corridors. Specifically, human activity and disturbance in crucial big game winter range is restricted from November 15th to April 30th if ungulates are present in the area (Bridger-Teton NF Plan 2015). Research conducted in Alberta suggests that elk start avoiding areas when road densities exceed 0.6 to 0.9 mi/mi^2 (1 to 1.5km/km^2) (Frair et al. 2008). The average roads per square mile on the BTNF is

Figure 19: Footprints road density summary

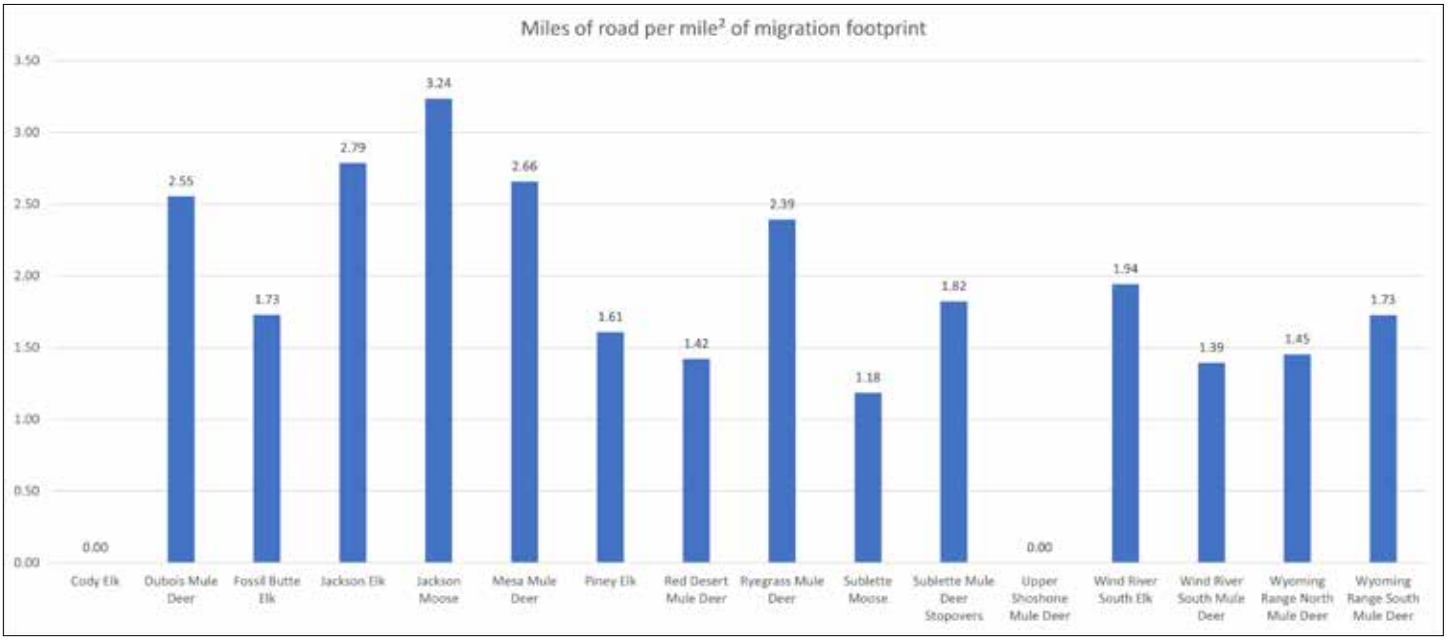


Figure 20: Crucial range road density summary

Herd Name	Total Roads Miles	Total Area (miles²)	Road Density (miles / mile²)
Cody Elk	0.00	107.50	0.00
Dubois Mule Deer	83.67	213.70	2.55
Fossil Butte Elk	71.23	123.16	1.73
Jackson Elk	297.58	829.47	2.79
Jackson Moose	94.24	305.02	3.24
Mesa Mule Deer	171.61	456.00	2.66
Piney Elk	319.00	513.00	1.61
Red Desert Mule Deer	282.82	402.00	1.42
Ryegrass Mule Deer	116.19	278.00	2.39
Sublette Moose	93.70	111.00	1.18
Sublette Mule Deer Stopovers	92.14	168.00	1.82
Upper Shoshone Mule Deer	0.00	143.58	0.00
Wind River South Elk	65.47	127.20	1.94
Wind River South Mule Deer	14.04	19.57	1.39
Wyoming Range North Mule Deer	326.01	473.74	1.45
Wyoming Range South Mule Deer	169.95	293.41	1.73

Crucial Range Type	Total Roads Miles	Total Area (miles²)	Road Density (miles / mile²)
Bighorn Sheep Crucial Winter	19.17	34.09	1.78
Bighorn Sheep Crucial WYL	0.00	110.07	0.00
Elk Crucial Winter	127.00	222.17	1.75
Elk Crucial WYL	307.93	434.16	1.41
Moose Crucial Winter	4.89	3.20	0.65
Moose Crucial WYL	401.50	428.46	1.07
Mule Deer Crucial Winter	17.18	9.22	0.54
Mule Deer Crucial WYL	50.00	55.79	1.12
Rocky Mountin Goat Crucial WYL	7.00	4.89	0.70

Table 3: Migration pathways and crucial ranges road density summaries

3.27 mi/mi², within elk migration routes is 8.07 mi/mi², and within elk winter crucial ranges is 1.75 mi/mi², and within elk winter/yearlong crucial range is 1.4 mi/mi²; Figures 19 & 20; Table 3). In migration pathways and crucial ranges where road densities exceed these thresholds, it would benefit elk to reduce road densities through seasonal or permanent closures.

Implementing seasonal closures could additionally help by concentrating recreational activities, enabling ungulates habituate to human presence. Impacts from recreational activities increase when the activities occur over long periods of time, across large areas, and unpredictably (Harris et al. 2014). Concentrating activities, such as snowmobiling, to confined areas would reduce ungulate exposure, and potentially increase the disturbance predictability, thereby providing an opportunity for ungulates to habituate to activities in those specific areas.

In locations where impermeable barriers block migration corridors, wildlife crossing structures (e.g. underpasses, overpasses, fence passageways) could be erected. This type of project would be best facilitated in collaboration with other stakeholders. For example, the Wyoming Department of Transportation installed two underpasses and several miles of game-proof fencing to facilitate wildlife passage across Highway 789, protect wildlife and motorists, and maintain corridor connectivity (Kauffman et al. 2020).

Timber Harvest

It will take careful consideration to simultaneously support effective conservation and human economics interests, such as timber harvest. Timber harvest and prescribed burning may be used in combination to enhance forage production, while retaining patches

of young trees to provide desired understory cover (Flathead NF Plan 2018). Forest harvest plots can be placed strategically within the broader landscape. For example, when determining where a timber harvest unit should create a large clearing, it would be prudent to consider factors such as how it would fit within a broader network of wildlife habitat connectivity and wildlife security (e.g. proximity to open roads); whether there is visibility from areas with a high public use; how the clearing would hinder or help ungulates moving between habitat patches in winter; and how it impacts the retention of larger areas of late-successional forest in the vicinity of other large openings (Flathead NF Plan 2018).

In places where timber harvest is deemed acceptable within ungulate winter range areas, it would be beneficial to add as few roads as possible (Bitterroot NF Plan 1987). Ideal plans would design timber harvest projects to simulate natural conditions, taking into account patch sizes, shapes, connectivity, as well as species composition and age-class diversity (Caribou NF Plan 2003). In addition, logging can support ungulate habitat, such as reducing the dense Douglas-fir understory and mid-story while retaining more of the largest ponderosa pine and Douglas-fir so the forest canopy can provide snow interception, creating favorable thermal conditions (Flathead NF Plan 2018). Timber harvest can also be designed to support security habitat. When elk flee from ATVs, cyclists, equestrians, hikers, or other recreationalists, they often retreat to dense vegetation where they can hide from human view (Wisdom et al. 2018, BHA 2021). Coordinating timber harvest plans with roads and trails to ensure that sufficient cover habitat remains nearby could help protect ungulates.

Further, logging activities can support hunting and big game by planning harvest plans for security habitat. Ungulates would benefit from having access to locations farther than 1.7 miles from motorized roadways with greater than 13 percent canopy cover during archery season (Ranglack et al. 2017). Ungulates hunted during rifle season would benefit from having access to areas larger than 5,000 acres that are over 0.95 miles from motorized routes with greater than 9 percent canopy cover (Ranglack et al. 2017).

Energy Development

Within the BTNF, mitigating winter range impacts from energy development proves to be an ongoing challenge. Recent research on migration recommends setting standards for allowable disturbance within migration corridors to a level below that which will negatively impacts ungulates (Sawyer et al. 2013, Kauffman et al. 2020). For example, Sawyer et al. (2020) found that habitat with even as little as 3 percent surface disturbance from energy development was enough to strongly deter mule deer use. Currently, GAP data suggest that all of the mapped ungulate herds on the BTNF have migration routes and crucial ranges with less than 3 percent surface disturbance generated by energy, development, and other sources (Figures 21 & 22 ; Tables 4 & 5). Future energy operations should be

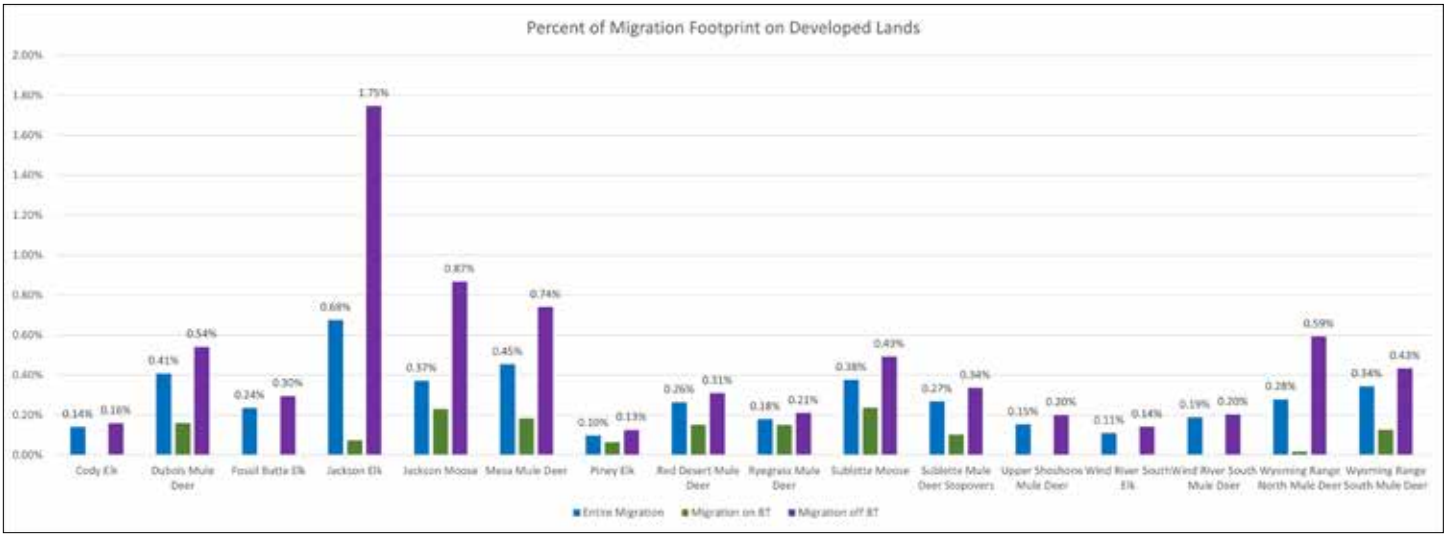


Figure 21: Migration footprints developed lands summary

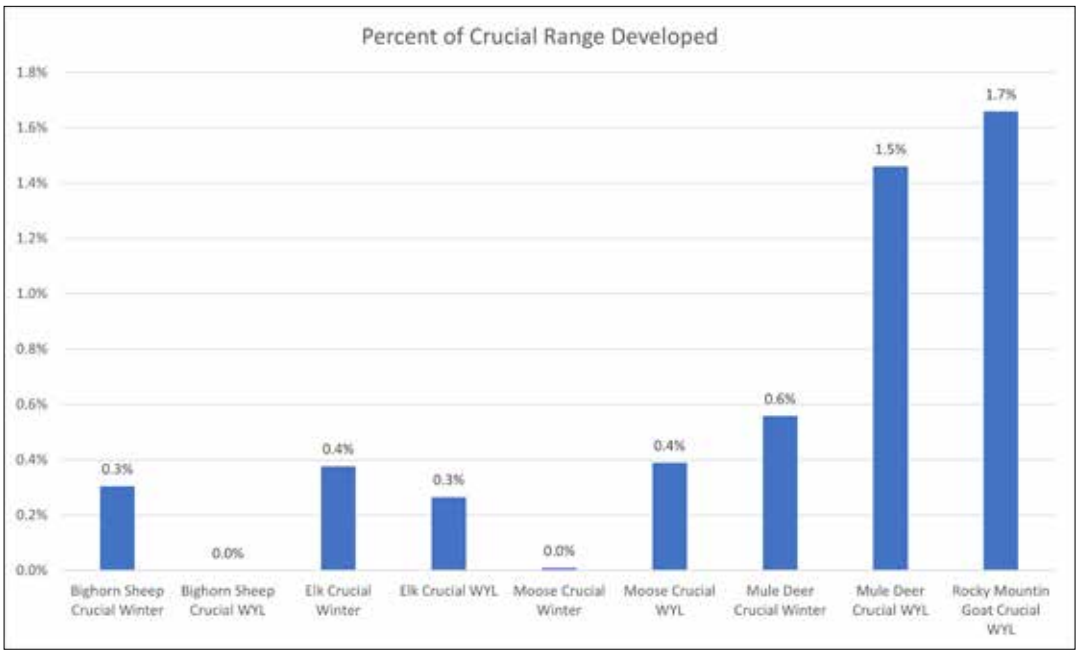


Figure 22: Crucial range developed summary

Herd Name	Total Footprint Area	Total Footprint Area on BT	Total Footprint Area off BT	Total Area Developed	Total Area Developed on BT	Total Area Developed off BT	Total prc Developed	Total prc Developed on BT	Total prc Developed off BT
Cody Elk	895.16	107.50	787.66	1.26	0.00	1.26	0.14%	0.00%	0.16%
Dubois Mule Deer	607.47	213.70	393.77	2.48	0.34	2.13	0.41%	0.16%	0.54%
Fossil Butte Elk	605.95	123.16	482.79	1.43	0.00	1.43	0.24%	0.00%	0.30%
Jackson Elk	1303.34	829.47	473.87	8.80	0.61	8.19	0.68%	0.07%	1.75%
Jackson Moose	391.67	305.02	86.65	1.45	0.70	0.75	0.37%	0.23%	0.87%
Mesa Mule Deer	868.27	447.15	421.12	3.94	0.82	3.12	0.45%	0.18%	0.74%
Piney Elk	1161.57	507.72	653.85	1.13	0.32	0.82	0.10%	0.06%	0.13%
Red Desert Mule Deer	1440.86	389.97	1050.89	3.81	0.59	3.22	0.26%	0.15%	0.31%
Ryegrass Mule Deer	562.21	272.38	289.82	1.01	0.41	0.60	0.18%	0.15%	0.21%
Sublette Moose	248.39	107.24	141.15	0.93	0.25	0.68	0.38%	0.24%	0.49%
Sublette Mule Deer Stopovers	571.00	164.63	406.37	1.53	0.17	1.37	0.27%	0.10%	0.33%
Upper Shoshone Mule Deer	607.31	143.58	463.72	0.93	0.00	0.93	0.15%	0.00%	0.20%
Wind River South Elk	578.13	127.20	450.93	0.64	0.00	0.64	0.11%	0.00%	0.14%
Wind River South Mule Deer	280.94	19.57	261.37	0.53	0.00	0.53	0.19%	0.00%	0.20%
Wyoming Range North Mule Deer	873.55	473.74	399.81	2.44	0.08	2.35	0.28%	0.02%	0.59%
Wyoming Range South Mule Deer	1006.22	293.41	712.81	3.46	0.37	3.09	0.34%	0.13%	0.43%

Table 4: Migration footprints developed summary

Crucial Range Type	Total Area	Total Area Developed	Percent Developed
Bighorn Sheep Crucial Winter	34.1	0.10	0.3%
Bighorn Sheep Crucial WYL	110.1	0.00	0.0%
Elk Crucial Winter	230.0	0.87	0.4%
Elk Crucial WYL	446.0	1.19	0.3%
Moose Crucial Winter	3.2	0.00	0.0%
Moose Crucial WYL	448.0	1.74	0.4%
Mule Deer Crucial Winter	9.2	0.05	0.6%
Mule Deer Crucial WYL	59.0	0.86	1.5%
Rocky Mountin Goat Crucial WYL	4.9	0.08	1.7%

Table 5: Crucial range developed summary

placed to avoid breaching this threshold and designed to accommodate migration to help prevent issues. For example, prohibiting surface-disturbing activities on winter deer and elk rangelands from November 15 through April 30 and on identified parturition areas from May 1 to June 30 (Bighorn NF Plan 2005). Within the BTNF forest plan, there are already restrictions on oil and gas development applied to crucial big-game winter range as identified and agreed upon by the Forest Service and Wyoming Game and Fish Department (Bridger-Teton NF Plan 2015).

Livestock and Fencing

Careful planning is necessary to support migration and livestock production in tandem. In some areas, livestock grazing may be used to promote palatable vegetation, such as facilitating aspen growth, or to suppress exotic invasive plants (Bridger-Teton NF Plan 2015, Mosley and Roselle 2006). In other areas, reducing livestock grazing during times when ungulates are migrating through the area could reduce conflict with big game. For example, some areas could be reserved for wildlife and watershed restoration work rather than grazed by livestock (Caribou NF PLAN 2003). In addition, livestock forage use levels could be set to leave sufficient forage remaining to support wintering ungulates (Bighorn NF Plan 2005). For example, livestock forage use on the Bitterroot National Forest is limited to 35 percent on partial retention big game winter range, and 50 percent on big game summer range (Bitterroot NF Plan 1987).

Though some types of livestock fencing is permeable to migrating ungulates, they still remain a hinderance in some contexts (Harrington and Conover 2006). Some species (e.g. pronghorn) are not as well-equipped to cross fences, and some fence designs (e.g. tall fences and woven wire) are less permeable than others (Gates et al. 2012). There is a great effort by conservation groups, wildlife, and land managers currently underway in Wyoming, retrofitting hundreds of miles of fence within identified migration corridors to be wildlife friendly (Kauffman et al. 2020). The BTNF has addressed some of these issues in the current forest plan. For example, the BTNF forest plan already stipulates that livestock fences should be modified to ensure that they don't create barriers to wild ungulate passage, such as replacing barbed wire with smooth wire, especially in calving areas (Bridger-Teton NF Plan 2015). The online tool could be used to identify specific areas where modifying fences to facilitate movement are especially important.

Forage Availability

Conversion of palatable native vegetation to exotic or noxious plant species is a growing issue for native ungulates (Kauffman et al. 2020). Fire can also be used to favor ungulate browsing and create desirable habitat conditions. For example, prescribed burns can be used to prevent catastrophic fires that decimate forage and allow annual grass and noxious weed invasion, as well as create staggered forage succession preferred by ungulates (Kauffman et al. 2020). Additionally, prescribed fire can be used to reduce conifer presence and favor aspen, an important browse species for ungulates (Boise NF Plan 2010). Fire can be used to manage vegetation for a variety of age groups. For example, important shrub species can be managed such that a diversity of successional stages are present, approximately one-third early, one-third mid, and one-third late (Bighorn NF Plan 2005). The BTNF forest plan has extensive and detailed strategies addressing specific habitat restoration guidelines.

Research and Education

The BTNF Forest Plan explicitly recognizes the need for local field research to inform policy and management. For example, the current forest plan emphasizes the importance of pursuing research on maintaining habitat for resident elk, migration corridors, calving areas, moose summer and winter range, and fisheries (Bridger-Teton NF Plan 2015). The current BTNF plan was established in 1990 and amended in 2015; given that plans are designed to be thoroughly revised every 15 years, the current plan is long overdue for re-evaluation. Updating this plan will necessarily involve incorporating best available scientific information to date.

In addition to incorporating new research to the plan, educating the public could help create cultural norms and appetite for protecting ungulate migration. Increasing signage, engagement on social media, and other outreach efforts could all build understanding of and support for compliance with migration preservation policies. For example, open areas where people are likely to see migrating ungulates provide opportunities for educational signage letting people know how to enjoy big game while avoiding disturbing the wildlife.

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