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Ungulate Migrations of the Western United States, Volume 2

Scientific Investigations Report 2022–5008

U.S. Department of the Interior
U.S. Geological Survey

Cover. Photograph from Mark Gocke, Wyoming Game and Fish Department.

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By Matthew Kauffman, Blake Lowrey, Jeffrey Beck, Jodi Berg, Scott Bergen, Joel Berger, James Cain, Sarah Dewey, Jennifer Diamond, Orrin Duvuvuei, Julien Fattebert, Jeff Gagnon, Julie Garcia, Evan Greenspan, Embere Hall, Glenn Harper, Stan Harter, Kent Hersey, Pat Hnilicka, Mark Hurley, Lee Knox, Art Lawson, Eric Maichak, James Meacham, Jerod Merkle, Arthur Middleton, Daniel Olson, Lucas Olson, Craig Reddell, Benjamin Robb, Gabe Rozman, Hall Sawyer, Cody Schroeder, Brandon Scurlock, Jeff Short, Scott Sprague, Alethea Steingisser, and Nicole Tatman

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)

Datum

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Abbreviations and Acronyms

ADOT	Arizona Department of Transportation
AZGFD	AZGFD
BBMM	Brownian bridge movement model
BIOS	Biogeographic Information and Observation System
BLM	Bureau of Land Management
BMV	Brownian motion variance
CDFW	California Department of Fish and Wildlife
CDOT	Colorado Department of Transportation
CPW	Colorado Parks and Wildlife

CMT	Corridor Mapping Team
DOD	U.S. Department of Defense
DOI	U.S. Department of the Interior
EPA	U.S. Environmental Protection Agency
FWP	Fish, Wildlife and Parks
GMU	game management unit
GPS	global positioning system
IDFG	Idaho Department of Fish and Game
ha	hectares
km	kilometers
km^2	square kilometer
MDT	Montana Department of Transportation
mi	miles
mi^2	square miles
NAD 83	North American Datum of 1983
NAVD 88	North American Vertical Datum of 1988
NDOW	Nevada Department of Wildlife
NSD	Net-squared displacement
NGVD 29	National Geodetic Vertical Datum of 1929
NMDOT	New Mexico Department of Transportation
NMDGF	New Mexico Department of Game and Fish
NMSU	New Mexico State University
NRCS	Natural Resources Conservation Service
ODFW	Oregon Department of Fish and Wildlife
ppm	parts per million
RMEF	Rocky Mountain Elk Foundation
ROW	right of way
USFS	U.S. Forest Service
USDA	U.S. Department of Agriculture
UDWR	Utah Division of Wildlife Resources
USGS	U.S. Geological Survey
VHF	very high frequency
WGFD	Wyoming Game and Fish Department
WHCWG	Washington Wildlife Habitat Connectivity Working Group
WDFW	Washington Department of Fish and Wildlife

WMA	Wildlife Management Area
WSDOT	Washington State Department of Transportation
WSOFM	Washington State Office of Financial Management
WVC	wildlife-vehicle collisions

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Abstract

Migration is widespread across taxonomic groups and increasingly recognized as fundamental to maintaining abundant wildlife populations and communities. Many ungulate herds migrate across the western United States to access food and avoid harsh environmental conditions. With the advent of global positioning system (GPS) collars, researchers can describe and map the year-round movements of ungulates at both large and small spatial scales. The migrations can traverse landscapes that are a mix of different jurisdictional ownership and management. Today, the landscapes migrating herds traverse are increasingly threatened by fencing, high-traffic roads, oil and gas development, and other types of permanent development. Through the use of GPS collars, a model of science-based conservation emerged in which migration corridors, stopovers, and winter ranges can be mapped in detail, thereby allowing threats and conservation opportunities to be identified and remedied. In 2018, the U.S. Geological Survey (USGS) assembled a Corridor Mapping Team (CMT) to work collaboratively with western states to map migrations of *Odocoileus hemionus* (mule deer), *Cervus canadensis* (elk), and *Antilocapra americana* (pronghorn). Led by the USGS Wyoming Cooperative Fish and Wildlife Research Unit, the team consists of Federal scientists, university researchers, and biologists and analysts from participating State and Tribal agencies. The first set of maps described a total of 42 migrations across 5 western states and was published in 2020 as the first volume of this report series. This second volume describes an additional 65 migrations mapped within 9 western states and select Tribal lands. As the western United States continues to grow, this report series and the associated map files released by the USGS will allow for migration maps to be used for conservation planning by a wide array of State and Federal stakeholders to reduce barriers to migration caused by fences, roads, and other development.

Introduction

Early explorers and naturalists have long known many ungulates (hooved mammals) in the western United States migrate seasonally. Some of the first managers of these herds

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also knew of their movements from many years of observation. But with the advent of global positioning system (GPS) collars, wildlife managers and researchers documented seasonal migrations with great precision. Indeed, many GPS collars can provide hourly locations for several years, which allows researchers to visualize year-round movements of ungulates at both large and small scales. Common outcomes of such studies are tracking datasets revealing migrations to be longer, more diverse, and more expansive than previously recognized. For example, partial migration, in which a portion of a population is migratory while the remaining individuals are resident on a shared winter range, can help herds diversify their migratory behaviors and result in more stable population dynamics (Lowrey and others, 2020). Some studies led to surprising discoveries of new migrations for herds previously thought to be resident (Sawyer and others, 2016). In addition to documenting new migrations, these tracking studies yielded new insights into the ecology of migration. Recent studies quantified the foraging benefit of migration (Aikens and others, 2017; Middleton and others, 2018) and provided evidence for the importance of learning and cultural transmission in the development and maintenance of migratory behavior (Jesmer and others, 2018; Brakes and others, 2019) and diversity (Lowrey and others, 2019; 2020). Research also revealed a growing human footprint is limiting animals' ability to undertake seasonal movements with increasing threats from roads, urban areas, and other man-made blockages to historical migratory routes (Lendrum and others, 2012; Sawyer and others, 2013;). The picture that emerged from this body of research is seasonal migration is a behavior essential to the health of many herds but is increasingly threatened for many ungulates throughout the United States and globally (Kauffman and others, 2018; Tucker and others, 2018). Because migration can benefit population dynamics, its loss can have negative consequences for the many herds that depend on seasonal movements to persist (Van Moorter and others, 2020).

As migration data become more commonplace, and potential barriers expand, planning to minimize disturbance to migration corridors has become a common goal for State and Federal managers (Middleton and others, 2020). However, it is not always clear from raw GPS tracking data where to focus conservation efforts with the highest value. A solution to this problem was put forward by Sawyer and others (2009), who used Brownian bridge movement models to estimate a width of each migration route and then combine the individual migrations into a population-level corridor (Horne and others, 2007). This method can be used to delineate low-, medium-, and high-use corridors as well as stopover areas where animals spend extended time foraging during migration (Sawyer and Kauffman, 2011). In addition, similar methods can be used to identify and map important population-level winter and summer ranges. This approach to mapping corridors and seasonal ranges with empirical data provides a straightforward means to identify threats and conservation opportunities across the landscapes migrations traverse or important seasonal habitat areas (Kauffman and others, 2018). Many State wildlife agencies across the western United States have been collecting GPS tracking data revealing a wide diversity of migrations, and interest in mapping corridors and seasonal ranges continued to grow throughout the 2000s. In 2018, the U.S. Geological Survey (USGS) forged a collaboration with participating western states, working together to leverage existing expertise towards mapping ungulate migration corridors and winter ranges across the West. In 2020, Volume 1 of this report series was published (Kauffman and others, 2020a, 2020b), mapping and describing migrations and winter ranges from 42 herds across 5 states. This report, Volume 2, details migrations and seasonal ranges from an additional 65 herds across most western states.

Migration corridor mapping emerged as a powerful means to advance conservation and maintain free animal movement along corridors. Because such maps can identify the key landscapes the majority of animals move through, they can be used to readily identify both existing and potential future barriers to movements and the conservation solutions to mitigate such threats (Kauffman and others, 2021). For the three main threats migrating animals face—fences, roads, and development—maps are instrumental in guiding on-the-ground conservation efforts for wildlife and land managers across many western states. Numerous examples now exist of such science-based conservation to sustain migration corridors.

The network of roads and highways, especially those with high traffic levels, are a clear threat to the persistence of migration. Numerous examples exist where movement data show truncated or impaired movements around roads, especially interstate highways with high traffic levels (Sawyer and others, 2010). Often, road-crossing structures lead to a substantial reduction in wildlife-vehicle mortalities. For example, along a stretch of U.S. Highway 97, biologists of the Oregon Department of Fish and Wildlife and the U.S. Forest Service recognized an east-west migration of mule deer across the highway causing high levels of wildlife mortalities (Coe and others, 2015). Working in collaboration, they installed two underpasses with associated fencing in 2012. The underpass installed at the Lava Butte location along U.S. Highway 97 reduced wildlife-vehicle collisions by approximately 90 percent compared to baseline data collected prior to construction (fig. 1).

Numerous agencies and conservation groups are working to modify fences to facilitate ungulate movements. Common across many western landscapes where animals migrate, fences vary in their function and design, which affects the degree they pose as a barrier to ungulate movement (Jakes and others, 2018). Tall, woven wire fences can be a complete barrier for many migrating animals. The common sight of an ungulate carcass tangled in a fence is a reminder fences can cause direct mortality. More importantly, however, fences can dramatically alter movement patterns, potentially severing migrations or altering timing and access to key resources (McInturff and others, 2020; Robb, 2020; Xu and others, 2021). Detailed migration maps can pinpoint where migrating animals must contend with fences during migration and thus identify conservation opportunities to improve safe passage. Most State

Figure 1. Lava Butte underpass being used by a pair of mule deer in south-central Oregon. Since the underpass was constructed in 2012, mule deer-vehicle collisions have been reduced by nearly 90 percent along this stretch of U.S. Highway 97. [Photograph from Leslie Bliss-Ketchum, Samara Group LLC.]

wildlife agencies and Federal land management agencies use migration maps or tracking data to identify problematic fences and target them for retrofit or removal. For example, the Arizona Game and Fish Department worked with the National Park Service, U.S. Forest Service, Arizona Department of Transportation, sportsman's groups, and local ranchers to inventory and then modify or remove barrier fences identified from GPS movement data. In 2018 and 2019, the Arizona Antelope Foundation and volunteers from across the state modified five miles of fences in critical locations to facilitate migration of *Antilocapra americana* (pronghorn), which are reluctant to jump fences. In total, about 55 miles of fences were removed or modified for the north and south of Interstate 40 pronghorn herds (fig. 2). Additionally, fence setbacks along key stretches of U.S. Highway 180 in Arizona assisted in greater permeability for pronghorn to reach winter range.

Housing developments in the West are a growing constraint on migrating animals, because they bring fences, roads, dogs, and people and are a permanent loss of habitat. Although before and after data are almost always lacking, it is nevertheless clear the development of large tracts of private ranchlands into housing has altered or truncated many migrations in the West (Sawyer and others, 2009, Tucker and others, 2018). Migration maps can guide conservation solutions. For example, The Nature Conservancy in Wyoming used funds from the Regional Conservation Partners Program of the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) to purchase easements on properties in the Greater Yellowstone Ecosystem that migrating *Cervus canadensis* (elk) and *Odocoileus hemionus* (muledeer), traverse or rely on for winter range. Because of the intactness of open rangelands, many ranchers have essentially been stewarding the habitat underpinning migration for generations. Thus, conservation easements that allow ranching to continue, rather than conversions to subdivisions, are a positive solution to sustain migration and maintain the multiple functions of working lands.

One of the most progressive approaches to planning for migration amid private land development is unfolding for

Figure 2. Volunteers modify a problematic fence constraining movement along a migration corridor used by pronghorn herds near Interstate 40 in Arizona. [Photograph from Arizona Game and Fish Department.]

a mule deer migration in Utah. Beginning in 2018, biologists at the Utah Division of Wildlife Resources captured and collared 46 mule deer, which revealed an existing migration that traversed lands within Eagle Mountain, Utah. A map of the migration revealed mule deer movements through still undeveloped lands around the town (Utah Division of Wildlife Resources, unpublished data). In response, the mayor and city officials moved to include the corridor in the city's Parks and Open Space Master Plan, the first city in Utah to do so. The new zoning regulation will include fencing, roadway mitigation, and limits to development within the existing corridor. Proactive planning like this for migrations traversing urban or suburban areas remains rare in the West but is possible, once detailed migration maps are generated and made available to managers, planners, and conservationists.

Energy development on public lands is also a growing concern regarding migrating herds. And while the number of detailed tracking studies is growing, many leasing and development decisions are still being made in the absence of information on the location of migration corridors. This is occurring primarily because the necessary maps have been lacking. This situation is, however, starting to change. For example, after the State of Wyoming mapped and designated the migration corridor of the Sublette mule deer herd, the map was available to inform leasing on Bureau of Land Management (BLM) lands in the southern portion of the corridor (WGFD, 2016; Kauffman and others, 2020a, 2020b). After consulting a detailed map of the corridor, approximately 22,000 acres of leases on public lands were deferred because they were deemed too risky to the functionality of the corridor. By the end of 2019 alone, leases totaling 14,020 acres were deferred (BLM, 2019). This example makes clear that it is possible to use detailed maps to better plan for migrations on Federal lands by limiting development and disturbance within high-use portions of the corridors. Using directional-drilling technology can also help minimize the surface footprint of deep gas development intersecting with migration corridors, while still accessing resources located thousands of feet below the surface. As renewable energy (for example, wind and solar) expands into western rangelands, migration maps will be key to designing facilities to minimize effects to ungulates.

Migration of ungulates is facilitated by the free movement of animals along traditional corridors. Work studying animal movements has shown mapping migration corridors provides the foundation for science-based management and conservation to sustain migration across working lands. This report, Volume 2 in the series, provides additional migration and winter range maps making new conservation efforts possible and furthers the opportunity to conserve the landscapes on which migrating herds of the western United States depend.

State-Led Conservation Efforts in the Western United States

Many states in the western United States have a history of informing management through the insights gained by deploying GPS collars and monitoring animal movement. The resulting location datasets can be used locally to inform herd-specific management needs such as monitoring population trends, evaluating cause-specific mortality, or identifying important migration routes and seasonal ranges. Moreover, when aggregated across the state, location datasets can be used to develop statewide distribution maps for a given species or prioritize migration corridors and winter ranges at the statewide level. The collaboration leading to this report provides an opportunity for wildlife management agencies in western states to analyze and publish maps of migration corridors and seasonal ranges across jurisdictional boundaries. Additionally, and new for this volume, the report provides the conservation priorities, successes, and future directions of each of the western State wildlife agencies. These efforts, which can include conservation easements, highway crossing structures, and habitat improvement projects, are often guided by migration and seasonal range mapping, and provide a broad overview of ongoing efforts by the western states to conserve and manage ungulate herds throughout the region.

Arizona

From arid deserts to snow covered alpine habitats, migration is an important aspect in the ecology of many Arizona ungulates. Arizona's diversity of elevations, vegetative communities, and climates causes a wide range of conditions creating a diversity of variable migration strategies. Generally, ungulate migrations in the state are most common at high elevations with greater variability of seasonal conditions, such as throughout the Colorado Plateau in northern Arizona. In the lower elevation desert and chaparral regions of southern and central Arizona, however, seasonal movements can be more subtle, taking place in relation to drought, water availability, forage conditions, or disturbance. Arizona's ungulate migrations are complex. While in some habitats seasonal migration is required for survival, in other habitats populations persist within a year-round range (for example, resident). Additionally, both resident and migrant behaviors can persist within a single herd. This flexibility among individuals in a herd maximizes available food, water, and habitat across the landscape, which supports long-term herd resiliency (Lowrey and others, 2020).

The Arizona Game and Fish Department (AZGFD) has been tracking ungulate migrations for decades. Some of Arizona's oldest migration maps illustrate summer, transition, and winter ranges of mule deer on the Kaibab Plateau (Russo, 1964). Among the Kaibab Herd, significant efforts have been focused on the migration of mule deer between northern Arizona and southern Utah (Carrel and others, 1999). In the 1970s, one study used colored visibility collars on more than 700 elk to understand migrations of herds throughout the Mogollon Rim in central Arizona. In the 1980s to 1990s, migrations were documented with greater detail when very high frequency (VHF) telemetry studies were used to follow migrations of mule deer, pronghorn, and elk (Haywood and others, 1987; Brown, 1990; Brown and Ockenfels, 2007). As technology progressed, several studies employing GPS collars in the early 2000s focused on the effect of traffic on elk movements, noting seasonal increases of wildlife-vehicle collisions during the migratory period (Gagnon and others, 2007, 2013). From 2008 to 2014, a large-scale pronghorn GPS study was conducted in northern Arizona, showing detectable genetic differences between subpopulations separated by highways (Theimer and others, 2012).

Today, AZGFD continues to collect information on ungulate migrations by deploying hundreds of GPS collars on mule deer, pronghorn, elk, and *Ovis canadensis* (bighorn sheep) statewide. One of the largest research projects is focused on the proposed Interstate 11 corridor, which would traverse much of the state if constructed. Here, 115 mule deer and 24 bighorn sheep have been GPS collared to understand the potential effects of Interstate 11 on population connectivity. Another study is focused on evaluating mule deer use of wildlife crossing structures north of Tucson. In the San Francisco Peaks area, an ongoing study on mule deer migrations is documenting some of the longest migrations in the state. South of Interstate 40, pronghorn, elk, and mule deer are tracked to provide a clearer picture of migrations between the Verde Valley and Flagstaff. In central Arizona (game management unit [GMU] 18A), both pronghorn and mule deer are monitored to understand seasonal habitat use and human barriers to movement, which is helping guide landscape-level management. Finally, in eastern Arizona, AZGFD is working with New Mexico State University to deploy hundreds of GPS collars on elk for a habitat, migration, and predation study. More information and maps for many of these projects are included in this report volume.

Ungulate migration corridors in Arizona face several threats primarily related to human development. Broadly speaking, habitat loss and fragmentation threatens ungulate populations, because it reduces functional habitat through time with corresponding reductions in ungulate abundance. The growth of Arizona's human population has come with an increase in transportation infrastructure and traffic volumes. AZGFD has worked closely with the Arizona Department of Transportation (ADOT) to conduct ungulate movement research along stretches of roadways including Interstate 40, Interstate 17, U.S. Highway 89, State Route 77, State Route 260, and State Route 64. Many of these high-volume roads have become completely impermeable to pronghorn, and passage rates on certain stretches are below 10 percent of attempted crossings for elk and mule deer (Gagnon and others, 2013, 2015). However, there are opportunities to mitigate negative effects. For example, AZGFD studies have identified key locations for wildlife crossing structures when combined with wildlife funnel fencing, will facilitate safe passage. However, the current costs—and lack of dedicated funding for wildlife crossing structures—are prohibitive in moving these projects forward.

Prompted by the U.S. Department of the Interior Secretarial Order (SO) 3362 (Department of the Interior, 2018), AZGFD has taken a prioritized approach to the conservation of ungulate migration, working closely with partner agencies such as the U.S. Forest Service (USFS) and Bureau of Land Management (BLM). Together, these partners have identified five areas within the state with high potential for conservation opportunities (AZGFD, 2020). The AZGFD also increased its capacity for research and mapping efforts of migrations by partnering with Mule Deer Foundation and the USGS. The concerted efforts between these groups have channeled funding for habitat restoration projects across priority areas. Strong partnerships built on common goals show research and planning efforts can have positive outcomes for ungulate habitat, which will help ensure Arizona's wildlife populations continue to thrive.

This summary was prepared by Lucas Olson, Jeff Gagnon, and Scott Sprague for the Arizona Game and Fish Department.

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California

California is home to several ungulate taxa, including mule deer, elk, pronghorn, *Odocoileus hemionus columbianus* (black-tailed deer) and bighorn sheep. Many of the ungulate herds in California are migratory and inherently need large landscapes to persist, making them particularly vulnerable to habitat loss and fragmentation. Connectivity between seasonal ranges is therefore crucial to conserve these charismatic species and to facilitate their movement across the landscape. Because of annual and regional climate variation, ungulates display diverse movement behaviors throughout California, including seasonal migration between distinct ranges, year-round occupancy within a home range (for example, resident), and nomadic movements that are unpredictable from year to year. Human disturbance and habitat fragmentation caused by infrastructure and other barriers can inhibit these types of animal movement (Sawyer and others, 2013; Tucker and others, 2018). California's population is approximately 40 million people, and humans and wildlife are increasingly coexisting in semiurban environments. Strategies such as corridor conservation and road crossing structures, however, can help maintain connectivity. Mapping corridors and conserving connectivity for ungulate herds in California is a priority for the California Department of Fish and Wildlife (CDFW).

For California, this report includes 10 completed migration analyses (7 mule deer and 3 elk analyses). Approximately

44 total datasets (24 mule deer, 15 elk, and 5 pronghorn) are in progress throughout the state. In addition, numerous past and ongoing telemetry datasets throughout the state are now being collected and analyzed. In ungulates, migration is thought to be a learned behavior (Jesmer and others, 2018), which means it may be difficult to re-establish population-level migration corridors once they are lost. For herds depending on migration to support population dynamics, declines are likely to follow disruptions to migration patterns. With California's substantial and growing human population, it is therefore especially vital to prevent further declines because of habitat loss along movement corridors where possible. Migration is essential for ungulates to access seasonally available resources and is particularly important to those herds that summer in the Sierra Nevada. These individuals must move to lower elevations during winter to access food and escape the harsh snowy conditions of the high-elevation Sierra Nevada.

In addition to migration corridors, mapping and conserving high-use winter range habitat is also essential to maintain population viability of ungulate herds. The CDFW is collaborating with other State and Federal agencies, non-governmental organizations (NGOs), and other stakeholders on habitat projects improving connectivity. Corridor maps and tracking data helped to secure several large grants and aided planning efforts in recent years to identify, enhance, and improve the quality of ungulate winter range habitats and migration corridors. The Highway 89 road-crossing project, is a perfect example of how a team of biologists, educators, scientists, and local community representatives successfully worked together, informed by mule deer tracking data, to proactively reduce mule deer and wildlife mortality on a 25-mile section of highway with the installation of under crossings, fencing, and jumpouts. Moreover, a grant from the U.S. Department of the Interior Secretarial Order 3362 (Department of the Interior, 2018), funded GPS collaring projects in the Mono Mule Deer focus area east of Yosemite National Park and the Roosevelt elk focus area on the northern coast. A separate grant was recently awarded in Mono County that will improve ten miles of fencing and install highway signage to benefit mule deer by significantly decreasing wildlife-vehicle collisions. A recent focus on northeast California is the result of an in progress CDFW fine-scale connectivity analysis incorporating ungulate corridors to identify more general wildlife corridors and linkages as well as barriers to movement.

Habitat restoration in response to wildfires and prolonged drought will become more prevalent in the state, as will the continued prioritization of road crossing structures to enhance connectivity and reduce wildlife-vehicle collisions. Ungulate mapping products from this report will aid these efforts to maintain connectivity across various scales, from the individual home range to the species distribution scale.

Not all past collaring projects in California were implemented with migration as a primary objective. As a result, some of the historical datasets may not have adequate sample sizes or appropriate GPS fix frequencies to map corridors. However, CDFW is examining all available collar data to determine potential uses. Efforts to collect telemetry datasets for mule deer, elk, pronghorn, and bighorn sheep from across the state and store them in a centralized database are ongoing. For each dataset, we implement a rigorous cleaning and validation process to ensure accuracy. We then run the Brownian bridge movement models to produce migration corridors, stopovers, and winter ranges (Sawyer and others, 2009). Output data from the model then undergo expert review by CDFW biologists with extensive knowledge of specific herd movements prior to being finalized. CDFW coordinates with neighboring State biologists for interstate herds with transboundary migratory routes, and, if available, datasets are pooled. Notable transboundary projects include the Carson River mule deer herd (California-Nevada), Loyalton mule deer herd (California-Nevada), and Verdi-Truckee mule deer herd (California-Nevada). Final products are released to the public in the Biogeographic Information and Observation System (BIOS) CDFW online viewing platform (https://wildlife.ca.gov/Data/BIOS) and are downloadable. Each dataset includes metadata to provide a written record of the data collection and analysis procedures used.

This summary was prepared by Evan Greenspan, Julie Garcia and Melanie Gogol-Prokurat for the California Department of Fish and Wildlife.

Colorado

Colorado has more than 800,000 estimated big game animals, which includes 428,000 mule deer and *Odocoileus virginianus* (white-tailed deer), 294,000 elk, and 77,000 pronghorn, along with Rocky Mountain bighorn sheep, desert bighorn sheep, *Oreamnos americanus* (mountain goats), and *Alces alces* (moose). To conserve the state's robust big game populations and their habitats, Colorado Parks and Wildlife (CPW) uses a data-driven approach incorporating GPS collars to track animal movements, which has shown to be a powerful and effective tool to educate the public and guide conservation efforts.

Colorado's mountainous terrain creates low-elevation winter ranges in close proximity to high-elevation summer ranges, which often leads to shorter migration pathways that are dispersed rather than forming long, narrow corridors. This juxtaposition of seasonal ranges connected by short migrations often results in a greater concentration of herds in a given area. Although longer routes are necessary on some landscapes, they can expose animals to greater risks than shorter routes, while shorter routes enable animals to conserve energy for winter. Because both long and short migrations connect critical seasonal ranges, both are equally important to the respective herds where they occur.

Northwest Colorado has the largest mule deer and elk herds in the West, and segments of these herds migrate great distances (Lendrum and others, 2013). Both shorter-distance, dispersed migration pathways and long-distance routes are used by migrants in the same herd (fig. 3).

The CPW invests a large amount of time and financial resources to capture animals and deploy GPS collars to collect data on big game movements, migration, survival, and cause of mortality. On an annual basis, CPW captures 1,200–1,500 big

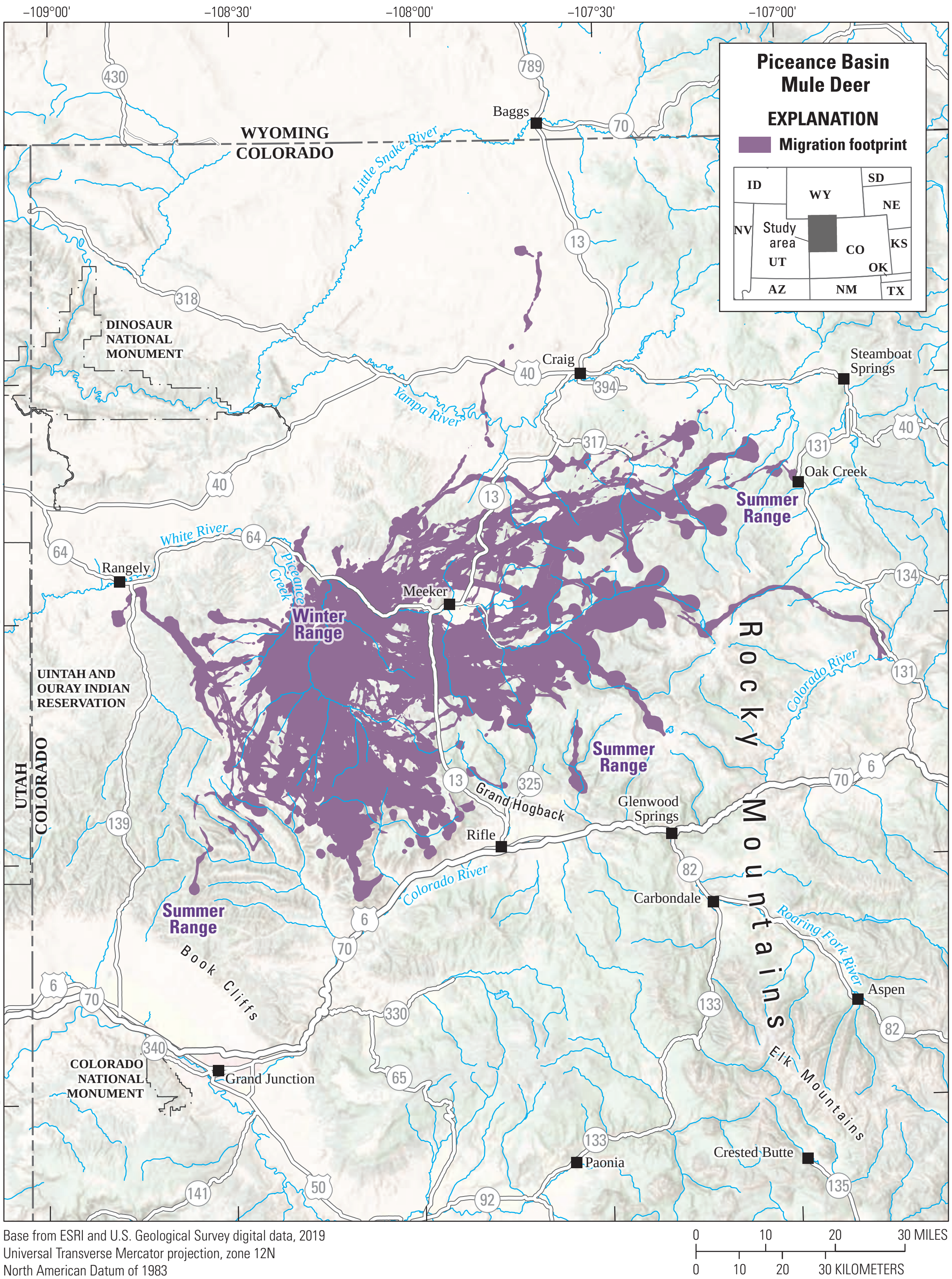

Figure 3. Brownian bridge movement models from 1,038 adult female mule deer from the Piceance Basin winter range (GMU 22) in northwest Colorado, 2008–2019 (C. Anderson, Colorado Parks and Wildlife, unpublished data). Mule deer were sampled opportunistically using helicopter net-gunning in early December of each year and fitted with global positioning system collars collecting 5 fixes per day for 16 months following deployment.

game animals through a combination of helicopter net-gunning, trapping, and darting. Most new studies are conducted with GPS collars, and the agency is in the process of upgrading to GPS collars for ongoing projects. Ongoing studies deployed GPS collars on mule deer, elk, pronghorn, Rocky Mountain and desert bighorn sheep, mountain goats, and moose. As of 2021, CPW is monitoring big game movements in more than 60 different projects (table 1), with elk and mule deer projects focused on the western mountainous part of the state (fig. 4).

Table 1. Number of Colorado Parks and Wildlife global positioning system collar projects by big game species and subspecies.

[GPS, global positioning system]

Wildlife species and subspecies	Number of GPS collar projects
Mule deer	16
Elk	22
Pronghorn	1
Rocky Mountain bighorn sheep	17
Desert bighorn sheep	3
Moose	2
Mountain goat	2

The CPW, Colorado Department of Transportation (CDOT), and numerous partners generated significant momentum in identifying, enhancing, and protecting big game winter range, migration corridors and movement pathways. The following list demonstrates recent collaborations, processes, and achievements in these efforts.

- The West Slope Mule Deer Strategy (2012–2014) was a comprehensive public engagement effort to guide future management actions with seven strategic priorities, https://cpw.state.co.us/Documents/MuleDeer/MuleDeerStrategy.pdf.
- The Highway 9 Project (2015–2016) was a collaboration resulting in a comprehensive wildlife crossing system including Colorado's first 2 wildlife overpasses and 5 underpasses connected by 10.4 miles of wildlife exclusion fence on State Highway 9 south of Kremmling, Colorado, https://cpw.state.co.us/hwy9.
- A 5-year monitoring study documented 112,678 successful passages by mule deer across the 7 structures established by the Highway 9 Project. During the same timeframe, carcass counts from wildlife-vehicle collisions decreased 90 percent relative to preconstruction levels, https://cpw.state.co.us/Documents/Conservation-Resources/SH9-Wildlife-Monitoring-Report.pdf.

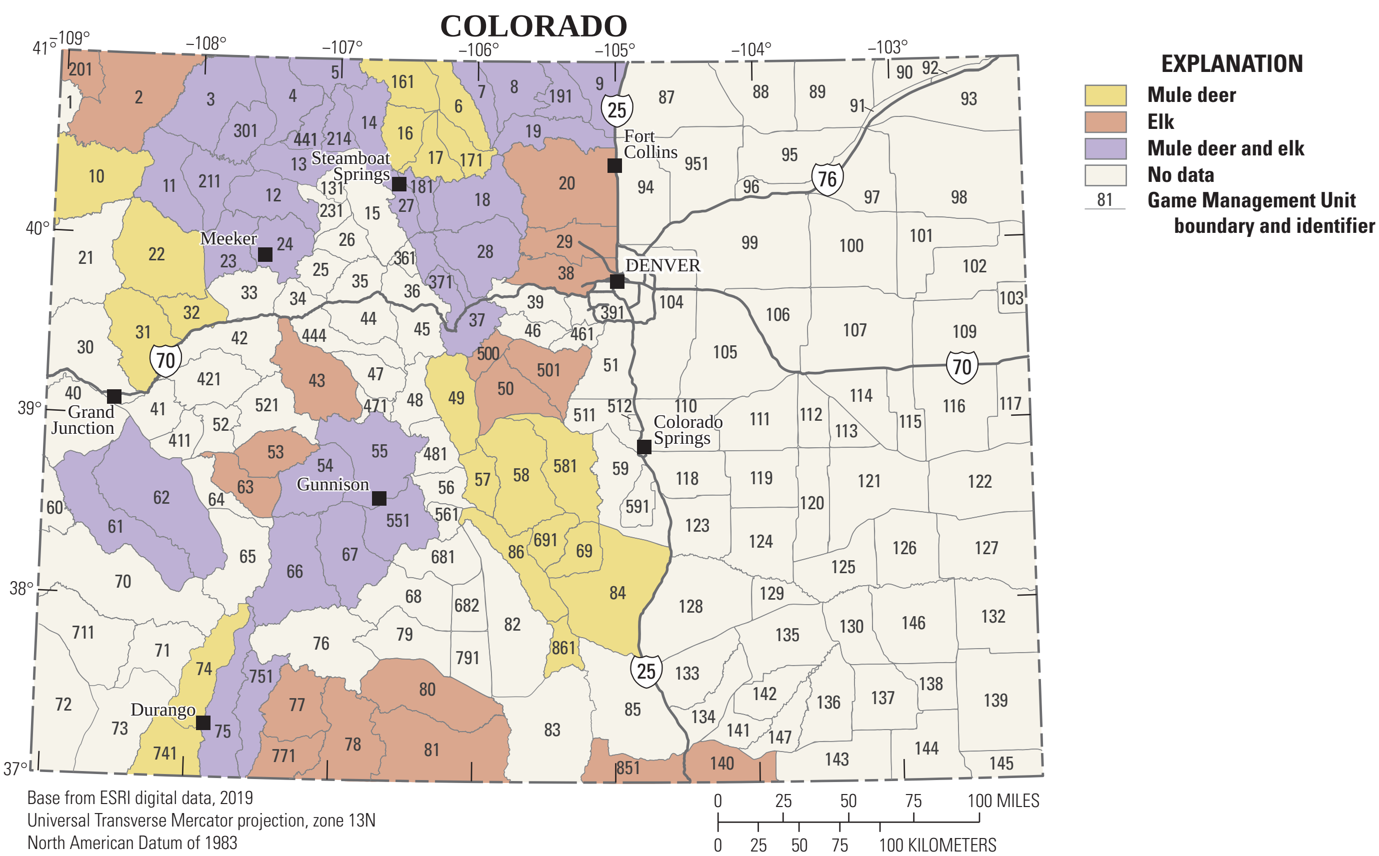

Figure 4. Mule deer and elk GMUs with ongoing global positioning system data collection projects in Colorado.

- The Western Slope Wildlife Prioritization Study (2016–2019) emerged from a commitment to increase collaboration between CDOT and CPW to address wildlife conflicts on roads. The study seeks to identify wildlife-highway conflict areas where targeted mitigation could have the greatest effect on reducing wildlife-vehicle collisions (WVCs). The project identified, mapped and prioritized highway segments across the Western Slope based on the risk of WVCs and the need for mule deer and elk to make cross-highway movements, particularly during migration or within winter range. As part of this project, Brownian bridge movement models were generated for all CPW GPS collar data on the Western Slope. This effort has been expanded to the East Slope and Plains Wildlife Prioritization Project. Once complete, Colorado will have a statewide planning tool for identifying and prioritizing wildlife mitigation and human safety projects, https://www.codot.gov/programs/research/pdfs/2019/WSWPS.
- The Wildlife and Transportation Summit (2017) established partnerships and developed an action plan to improve highway safety, protect wildlife populations, and their movement corridors, https://www.codot.gov/programs/environmental/wildlife/wildlife-transportation-summit.
- In 2018, the Colorado Wildlife Transportation Alliance was established as a statewide partnership between CDOT, CPW, Federal, Tribal, academic, nonprofit, biologist, and engineering partners. The Alliance is a collaborative effort with a vision to improve human safety, while fully integrating wildlife movement needs into Colorado's transportation system, https://www.coloradowta.com/.
- Since 2018, Colorado received several Secretarial Order 3362 (Department of the Interior, 2018) funding grants, totaling more than $500,000, to increase big game GPS data collection. In addition, CPW has published a statewide action plan related to Secretarial Order 3362 (Department of the Interior, 2018), which identifies high priority landscapes where the agency and its conservation partners will work to address threats to big game winter ranges and migration corridors.
- In 2019, Colorado Governor Jared Polis signed Executive Order D-2019–011: Conserving Colorado's Big Game Winter Range and Migration Corridors (Colorado Office of the Governor, 2019). This executive order directed both CPW and CDOT to work cooperatively to conserve Colorado's valuable big game resources. Additionally, it directed CPW to compile a big game status report to guide both agencies, as well as partners, to collectively improve the conservation of big game winter range and migration corridors.
- The CPW Commission adopted a resolution in support of Executive Order D-2019-011 (Office of the Governor, 2019). CDOT and CPW signed a Memorandum of Understanding in response to Executive Order D-2019-011, which directs the agencies to collaborate to support the Wildlife Transportation Alliance and the implementation of big game crossings.
- The CPW completed the 2020 Big Game Winter Range and Migration Corridors Status Report, as directed by Executive Order D-019-011. The CPW compiled the best available science on Colorado's big game populations, including population status and trends, monitoring and inventory methods, seasonal habitats and migration corridors, and conservation threats and actions. This report also outlines ongoing research and data gaps associated with Colorado's big game winter range and migration corridors. The CPW concludes this report with recommendations on a path forward to conserve these valuable habitats and populations.
- In 2019, the Colorado Legislature passed Senate Bill 19-181, which mandates increased protections for wildlife during oil and gas operations (Colorado Government, 2019). The CPW is defining and mapping big game bottlenecks as part of the Senate Bill 19-181.

The CPW and its partners will continue this momentum, expanding the integration of big game migration and movement data into land conservation efforts, herd management planning, and transportation systems.

This summary was prepared by Andy Holland, Michelle Flenner, Casey Cooley, Chuck Anderson and Michelle Cowardin for Colorado Parks and Wildlife.

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Colorado Office of the Governor, 2019, Executive order D 2019 011—Conserving Colorado's big game winter range and migration corridors: Colorado Office of the Governor, 4 p., accessed November 4, 2019, at https://www.trcp.org/wp-content/uploads/2020/04/D-2019-011.pdf.

Idaho

Migratory big game animals are an integral part of Idaho's culture, heritage, and economy. The Idaho Department of Fish and Game (IDFG) works with a diversity of partners to conserve and enhance big game seasonal and migratory habitats throughout the state. Partners of IDFG include State and Federal agencies, nongovernmental organizations, and private landowners. For decades, IDFG invested significant research and monitoring resources to obtain data necessary to aid and inform efforts to conserve seasonal big game habitats. Most recently, the management and conservation of key big game migrations has come into sharp focus for IDFG.

Recent technological advancements in GPS radio telemetry and innovations in statistical analyses greatly improved the quality of migration data and information available to inform big game management decisions. Since 2018, Secretarial Order 3362 (Department of the Interior, 2018) has augmented IDFG's longstanding radio-collaring efforts, with resources to apply these technologies for mapping priority big game migrations. The Idaho Secretarial Order 3362 Action Plan established a management and research framework with the aim of conserving both priority big game seasonal ranges and migration routes. IDFG specifically applied Secretarial Order 3362 (Department of the Interior, 2018) funding to analyze nearly two decades of GPS radio-telemetry data collected for mule deer, elk, and pronghorn from around the state and then map their migration routes and stopover areas.

Combining these modern technologies and Secretarial Order 3362 (Department of the Interior, 2018) funding, IDFG mapped 18 mule deer, 15 elk, and 5 pronghorn migrations as of 2021. These maps are the culmination of 18 years of capture, collaring, and data collection resulting in more than 4 million GPS locations from nearly 2,000 radio-collared individuals. Map files for Idaho's big game migration routes are digitally available through the Idaho Fish and Wildlife Information System (IFWIS; https://idfg.idaho.gov/data). These maps are used by IDFG and partners to improve big game management per the following examples:

- Design of transportation infrastructure to reduce wildlife-vehicle conflicts. A key focus is southeast Idaho, where IDFG is tracking mule deer to evaluate how they interact with U.S. Highway 30.
- Technical assistance to assess potential effects of proposed energy development projects on pronghorn migrations in eastern and south-central Idaho.
- Habitat improvement projects including retrofitting livestock fences to wildlife friendly specifications along migration routes across Idaho.
- Technical assistance to Federal and State land management agencies to protect and enhance migration habitat.

Efforts of IDFG to understand and conserve big game movements and migrations will continue, as there were more than 2,000 big game animals fitted with GPS radio collars in 2021 across Idaho. Data from these animals will be used to periodically update existing migration maps and develop new maps for big game migrations in other regions around the state. The IDFG is also planning to refine understanding of elk migrations in north-central Idaho by supplementing ongoing efforts with more radio-collared individuals in targeted areas. Lastly, new projects have begun in southern Idaho that describe presently unmapped mule deer migrations and their potential interactions with Interstate 84 and mining operations. Most importantly, these state-of-the art migration maps will be continually improved and available to inform big game management and conservation in Idaho.

This summary was prepared by Frank Edelmann and Matt Pieron for the Idaho Department of Fish and Game.

Montana

As part of its mission, Montana Fish, Wildlife and Parks (FWP) has a long history of conserving wildlife habitat, including those areas important for wildlife movement and migration. The agency works closely with private landowners, local government, State and Federal agencies, Tribes, and conservation groups ensuring wildlife have sufficient habitat and can move between seasonal ranges, within seasonal ranges, and when dispersing. Functional wildlife habitat allows for wildlife to move across the landscape at a variety of spatial and temporal scales to facilitate access to food, breeding, shelter, and to facilitate genetic exchange among populations or subpopulations. Some of the earliest research on big game migration was conducted by FWP staff along the front of the Rocky Mountains in the 1940s and 1950s. Moreover, FWP staff helped to develop some of the earliest wildlife telemetry collars for the purpose of monitoring movements, starting in the 1960s. Conserving habitat and improving landscape permeability for wildlife to move and migrate continue to be important management priorities in Montana.

Dating back to 1940, FWP collaborates with partners to conserve high-value wildlife habitats. For example, FWP completed more than 545,000 acres of permanent conservation easements, established 450,000 acres in the Wildlife Management Area (WMA) system, enrolled 260,000 acres of private lands into 30-year conservation leases, and enrolled 320,000 acres of private lands in shorter-term habitat enhancement and restoration contracts. Fence modifications and removals to promote or manage wildlife movement have been a focus in Montana since the 1950s. These projects are mostly collaborative efforts between FWP, regional landowners, and other partners who collectively work to improve habitats or conserve land owned or managed by other entities.

The focus of FWP on habitat conservation and management has been enhanced and expanded by Secretarial Order 3362 (Department of the Interior, 2018) and related Federal programs. Since the inception of funding programs for this initiative by the National Fish and Wildlife Foundation and USFWS Partners, partnerships throughout Montana have been awarded more than $2 million for locally led conservation easements, weed management, livestock grazing management, and fence modification efforts, matching additional millions of dollars raised for these efforts. Two local partnerships were recently awarded more than $10 million for conservation easements, habitat management, and habitat restoration efforts in two priority areas in the Montana Action Plan for Secretarial Order 3362 (Department of the Interior, 2018) by the NRCS Regional Conservation Partnership Program, again matching millions of additional dollars for these local efforts.

Emphasis on land use and transportation planning also increased in recent years within Montana. FWP staff engaged in and informed several county land-use planning efforts in recent years, at the request of county governments leading these efforts. For example, Gallatin County in southwestern Montana is in the process of developing a growth plan, and FWP supported this effort with information on wildlife movement and migration from within the county. FWP staff are also directly involved in several national forest planning efforts across Montana. Finally, transportation planning efforts incorporating wildlife movement and migration needs have long been a focus in Montana, which has among the highest density of wildlife accommodations on roads in the Nation (Huijser and others, 2016). These efforts increased in recent years. Biannual meetings of FWP and Montana Department of Transportation (MDT) staff have been established, together with shared databases and mapping systems, ensuring wildlife movement needs are considered in roadway improvement projects. A Montana Wildlife-Transportation Summit was held in 2018, bringing together hundreds of stakeholders furthering efforts integrating wildlife into transportation planning. As a result, a formal Memorandum of Understanding between FWP and MDT was ratified, establishing a Wildlife-Transportation Steering Committee composed of FWP, MDT, and several conservation groups. This Committee recently formed a data and information working group combining the relevant transportation and wildlife data identifying large-scale road segments of greatest need for wildlife accommodations on State-maintained roadways. This will pave the way for local partnerships developing specific plans for the locations of wildlife accommodations, such as overpasses or underpasses.

Instrumenting animals with telemetry collars remains an important aspect of the FWP science-based approach informing wildlife management. To this end, FWP and partners deployed GPS collars on more than 850 elk, 380 mule deer, and 490 pronghorn across Montana since the early 2000s. Moreover, FWP has approximately 1,200 GPS telemetry devices deployed on animals in 2021 from several taxa, including big game animals, nongame species, game birds, furbearers, and carnivores. The collection of these spatial data are fundamental to FWP research and management programs, and the resulting maps are used to directly inform habitat management and conservation as well as land-use and transportation efforts by local partnerships.

FWP works in collaboration with the Corridor Mapping Team delineating and mapping population-level seasonal ranges and migration routes for ungulate herds with existing GPS data. In 2020, FWP mapped 22 elk and 12 mule deer populations statewide and are expanding the efforts to include pronghorn, moose, and bighorn sheep (table 2). Other ongoing efforts include mapping seasonal ranges, dispersal routes, and migration routes of carnivores and nongame species.

While mapping seasonal ranges and migration routes is an important aspect of the Montana program, there are a number of sensitivities surrounding maps highlighting herd-specific migration and seasonal distributions. Review and discussion of the detailed seasonal range maps in local communities throughout Montana revealed several important issues, which can be summarized into three categories.

- Sampling: FWP deployed GPS collars in a small number of big game herds (compared to the overall number and distribution of herds), and on a relatively small (and sometimes nonrandom) sample of individuals within those herds. This leads to misleading representations of the extent of seasonal ranges and migration routes at large scales across the state and within specific herd ranges.

- Social: Specific private lands can be identified as important when viewing maps of big game seasonal ranges and migration routes with ownership in mind. Some private landowners were unaware such maps might be created and widely distributed when they granted FWP access to capture animals and deploy GPS collars for various research projects. Other private landowners did not grant FWP permission to capture animals, yet their lands are highlighted by the movements of animals equipped with collars. FWP staff have expressed concern the agency's relations with some landowners might be strained by the extra attention potentially coming from these kinds of maps, for various reasons. Private landowners are critical to wildlife management and conservation in Montana, and when conflicts arise, they can be detrimental to facilitating big game movement, migration, and other FWP conservation programs.

- Ethical: Detailed maps may compromise ethical standards of fair-chase hunting by providing an opportunity for hunters to focus on specific lands for which information is displayed. Increasing the availability of such maps may also spur additional uses (or information requests) beyond their intent, such as access on hunting-based smartphone apps or software, further exacerbating the issue. There are similar concerns about shed antler hunting and general wildlife-viewing activities.

While FWP supports the west-wide mapping effort, the agency is taking a locally led approach to outreach and communication regarding important seasonal ranges and migration routes, rather than releasing maps in public venues, such as this report. To this end, FWP regional staff are using maps when communicating directly with local landowners and interest groups. This approach ensures FWP can most effectively address regional concerns and sensitivities, yet still raise awareness and promote wildlife conservation in a manner consistent with FWP's movement and migration strategy.

More information on FWP's movement and migration strategy as well as mapping efforts across the state can be found at https://fwp.mt.gov/conservation/strategy-for-wildlife-movement-and-migration.

This summary was prepared by Justin Gude, Blake Lowrey, Nick DeCesare, and Kelly Proffitt for Montana Fish, Wildlife & Parks.

Table 2. Number of bighorn sheep, elk, moose, mule deer and pronghorn herds where global positioning system collars have been deployed across Montana and where Montana Fish, Wildlife & Parks is generating maps of seasonal ranges and migration routes.

Species	Number of herds
Bighorn sheep	10
Elk	21
Moose	4
Mule deer	12
Pronghorn	9

Selected Resources

Huijser, M.P., Hardy, A.R., Whisper, C., Grahm, J., Fairbank, E.R., Begley, J.S., Purdum, J.P., Basting, P., Allen, T.D.H., and Becker, D., 2016, US 93 North Post-construction Wildlife-vehicle collision and wildlife crossing monitoring on the Flathead Indian Reservation between Evaro and Polson, Montana: Montana Department of Transportation, Final Report, 144 p., accessed November 4, 2021, at https://www.mdt.mt.gov/other/webdata/external/research/docs/research_proj/wildlife_crossing/phaseii/PHASE_II_FINAL_REPORT.pdf.

Nevada

Nevada's basin and range topography hosts a wide diversity of migratory ungulates including pronghorn, mule deer, elk, and bighorn sheep among other nongame species. The extreme variability in climate from arid deserts to high alpine ecosystems facilitates a broad array of migration strategies in many herds. Individual animals may exhibit resident (occupy a consistent home range throughout the year), obligate (individuals are forced to leave summer range because of snow depth, extreme temperatures, or lack of forage on an annual basis), conditional, or partial (individuals may choose to migrate if local conditions change or stay close to breeding grounds year round) migratory behaviors. Nevada's mule deer populations have been on a downward trend in recent decades likely because of lack of consistent precipitation, large-scale rangeland fires, the conversion of native shrubs to invasive grasses, and degraded range conditions from livestock, feral horses, and feral burros. In response to these declines, Nevada Department of Wildlife (NDOW) recently charted a Mule Deer Enhancement Program led by teams of local area biologists, stakeholders, and members of the public. The overall goal of this effort is to identify factors limiting the population growth, and thus abundance of mule deer herds, including conducting habitat assessments for each herd, identifying projects to enhance mule deer habitat, and developing a risk assessment of several key migration corridors (fig. 5).

Nevada has about 70.4 million acres of total land area, and 49.5 million acres (70.3 percent) are managed by three U.S. Department of Interior (DOI) agencies: BLM (47.2 million acres), USFWS (1.5 million acres), and NPS (0.8 million acres). An additional 5.8 million acres are managed by the USFS. In contrast to the 55.3 million acres (78.5 percent) managed by these four Federal agencies, 9.2 million acres (13.0 percent) are privately owned and managed across the state. Nevada is unique with such a large proportion of public lands managed under multiple-use mandates (Congressional Research Service, 2020). Because of this, collaborative Federal-State partnerships are important to preserving crucial winter range and movement corridors.

When Secretarial Order 3362 (Department of the Interior, 2018) was signed, Nevada developed a comprehensive action plan identifying the top five priority migration corridors for mule deer including the Ruby Mountain, Pequop, Izzenhood, South Tuscarora, and Sheep Creek herds in eastern Nevada. Together, these herds comprise approximately 50 percent of the statewide population of mule deer in Nevada. Additionally, Nevada identified two pronghorn herds in the northern half the state for additional research by radio-collaring efforts to better delineate migration corridors and winter range use. Along with mapping migration corridors and winter range use for these herds, several key habitat priorities were identified through this process.

For habitat projects in 2019–2020, NDOW and our Federal partners focused on stopovers and crucial winter range within our top five priority mule deer herds. More than 7,600 acres of habitats were treated or restored with native vegetation and herbicide treatments in the Area 6 mule deer herd. For the Area 10 (Ruby Mountains) mule deer herd, NDOW worked with Rocky Mountain Elk Foundation (RMEF) and the U.S. Navy securing a conservation easement for approximately 2,151 acres of crucial winter habitat also serving as a major stopover area. This easement will permanently protect these lands from development. In 2019 and 2020, Nevada received funding to enhance more than 8,000 acres of crucial winter and stopover areas. Additionally, NDOW received a U.S. Fish and Wildlife Service (USFWS) Partners for Fish and Wildlife (PFW) grant to treat 680 acres of invasive *Taeniatherum spp*. (medusahead) on private lands helping recover native vegetation on a crucial wintering area for mule deer. In the Area 7 (Pequop) mule deer herd, NDOW worked with the Mule Deer Foundation and PFW to replace more than 4 miles of poor-quality range fence with wildlife

Figure 5. Mule deer buck along the east face of the Sierra Nevada, Washoe County, Nevada 2013. [Photograph from Tim Torell, Digital Wildlife Images.]

friendly fencing in 2020. The NDOW has worked with the BLM to treat more 4,000 acres of winter range burned in the 2018 and 2019 Hogan and Shafter fires.

For 2020–2021, ongoing research projects focused on analyzing pronghorn GPS collar data and implementing monitoring and assessment of habitat treatments across the state. NDOW has partnered with the BLM to expand the scope and increase the sample size of radio collars in northwest Nevada, including portions of Lassen and Modoc Counties, California. Preliminary pronghorn migration maps have been drafted and shared with partnering agencies in Oregon, California, and Idaho. An interstate collaborative study between Oregon, Nevada, and Idaho will be initiated in the 2021 fiscal year.

New for 2021, Nevada has worked with California to map three interstate corridors for mule deer in the Sierra Nevada range, and one pronghorn migration corridor using portions of the Hart Mountain National Antelope Refuge in Oregon and the Sheldon National Antelope Refuge in Nevada. Mule deer and pronghorn corridors can be found in the Nevada sections of this report.

This summary was prepared by Cody Schroeder for Nevada Department of Wildlife.

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New Mexico

As the fifth largest state in the United States, New Mexico has many diverse landscapes. The southern extent of the Rocky Mountains ends in central New Mexico and is bracketed by mesas and canyons. Further south, the Chihuahuan Desert begins, and desert basins separate the sky island mountain ranges. In eastern New Mexico, rolling plains and sandhill habitats are present. Habitats range from alpine tundras reaching 13,161 feet at the highest peak, conifer and aspen woodlands and shrublands in the midelevations, and shrublands and grasslands in the desert valley floors around 4,000 feet.

Because of the diverse landscape and elevational gradient, big game winter range and summer range vary by location within the state. Some big game populations are known to travel between summer and winter ranges on a seasonal basis, while others move across the landscape in response to shifts in local environmental conditions. However, best available information for most areas is based on expert knowledge, and detailed big game migration routes from GPS-tracking data are generally lacking throughout much of the state.

The lack of big game GPS movement data are the primary obstacle in effective management of big game corridors and key ranges in New Mexico and makes it difficult to provide informed guidance related to new infrastructure, urban development, or resource management plan updates. Certainly, increased development, new barriers, and habitat degradation will continue to inhibit existing ungulate movements across the New Mexico landscape. Because of this, the New Mexico Department of Game and Fish (NMDGF) is working to gather more migration data to help guide future development planning and habitat improvements in a manner that preserves important movement corridors, ranges, and seasonal-use areas to promote resilient big game populations.

Expert knowledge and previous research found mule deer and elk herds in northern New Mexico make long-distance migrations between summer ranges in Colorado's San Juan Mountains and winter ranges in New Mexico's northern landscape (Sawyer and others, 2019; Tator, 2016; Kyle Tator, Jicarilla Apache Game and Fish Department, unpublished data communication). In addition, big game herds in some parts of the state may make seasonal movements or short-distance elevational migrations in response to winter snowpack and spring green up (see Mt. Taylor, Jemez Mountains, and Gila sections of this report). In southern New Mexico, big game herds often do not have distinct summer and winter areas; rather these populations tend to make movements in response to environmental occurrences like precipitation or drought. Although these populations typically do not migrate long distances, they are no less ecologically and socially important. Their persistence is dependent on their ability to move across the landscape in a manner maximizing their fitness and maintains herd productivity.

The NMDGF recently began deploying GPS collars to identify migration routes of targeted herds, but biologists have only been able to deploy collars in a small fraction of potential areas because of funding limitations. Thus, as with most states, the lack of mapped movements in a particular area does not indicate the herds do not make seasonal movements in those areas. Rather, it is more likely there has yet to be any GPS-collaring studies in a particular location.

Beginning in 2019, several hundred elk were marked with GPS collars in the Gila landscape as part of a predator-prey interaction study. This GPS data will also be used to identify how elk use the landscape. This is a collaborative study between the NMDGF, New Mexico State University (NMSU), USGS, and the AZGFD. Furthermore, the NMDGF and the USGS recently obtained funding through Secretarial Order 3362 (Department of the Interior, 2018) to map deer, elk, and pronghorn migration corridors in northern New Mexico. Initiated in 2020, data from this project are actively being collected and results will be published at the conclusion of the research.

The NMDGF intends to use big game movement data to make informed management recommendations and to implement habitat improvement projects across the state. Prior to GPS collaring studies, most of these management decisions were based on expert knowledge of wildlife biologists and game wardens. With the newly obtained GPS-location data, the NMDGF will be better prepared to make informed and more specific recommendations protecting and improving habitat use by big game.

New Mexico took an important step to ensure wildlife migrations and habitat connectivity are protected with the passage of the 2019 New Mexico Wildlife Corridors Act (New Mexico Government, 2019). This act directed the NMDGF and the New Mexico Department of Transportation (NMDOT) to collaborate and identify where wildlife movement corridors pose a risk to the traveling public and develop a plan to address these issues. The provisions of the act do not apply to private property or private property owners unless those owners voluntarily choose to participate. The act focuses on mule deer, elk, pronghorn, bighorn sheep, black bear, mountain lion, and species of concern, defined as "* * * species identified by the NMDGF as being adversely affected by habitat fragmentation exacerbated by human caused barriers and the high potential for wildlife-vehicle collisions." Specifically, the act was created to help identify and prioritize areas across the state where barriers may inhibit wildlife movement within and among habitat patches and between ranges. Our research team analyzed available movement data and NMDOT wildlife-vehicle collision data to identify priority areas. In 2020, 10 priority areas will be identified and field evaluated for potential mitigation projects for wildlife. Priority areas will be updated as new information becomes available.

The NMGFD emphasizes more work is needed to identify important seasonal ranges and movements for most of New Mexico's ungulate herds. Additional research will provide science-based information assisting with identifying critical corridors or seasonal ranges across these landscapes, and it will narrow the focus of conservation and management activities. Without this data, managers will be less effective in engaging with stakeholders guiding work or management that would benefit big game species.

The southeastern plains landscape is a high priority for the NMDGF as it is becoming an increasingly human landscape, and there are no big game movement data helping guide future management recommendations. Mule deer and pronghorn in this area are thought to make movements to take advantage of seasonal weather patterns. These movements are critical for the animals to meet their energy demands and complete their annual life cycle. If their ability to move is impeded, they may not be able to acquire the necessary resources. Their fitness, ability to rear young, and survival may be reduced and ultimately could cause populations to decline. Because of the human effects in southeastern New Mexico, the movements of pronghorn and mule deer may be constrained by the development of new infrastructure, and population persistence may be challenged.

This summary was prepared by Orrin Duvuvuei and Nicole Tatman for the New Mexico Department of Game and Fish.

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Oregon

The Oregon Department of Fish and Wildlife (ODFW) has long had a focus on providing connectivity of habitat for the broad array of wildlife species throughout Oregon, and this has increasingly included the seasonal migratory corridors of ungulates. Barriers to animal movement is one of seven Key Conservation Issues (KCI) outlined in Oregon's State Wildlife Action Plan, known as the Oregon Conservation Strategy (Oregon Department of Fish and Wildlife, 2016). The ODFW identified seasonal ranges and migration corridors across most of the range of mule deer in the state by analyzing movement patterns of 1,868 mule deer equipped with GPS collars between 2005 and 2021. Analysis of nearly 2.25 million data points using net-squared displacement has identified dates, timing, and durations of seasonal range use and migration periods. Migration corridors have been identified using either Brownian bridge movement modeling (Coe and others, 2015) or kernel density estimation of migration path segments (D.G. Whittaker, ODFW, unpublished data) depending on the programmed frequency of locations for individual animals (fig. 6**)**. Migration corridors from these analyses are used to identify placement of key crossing structures along U.S. Highway 97 in central

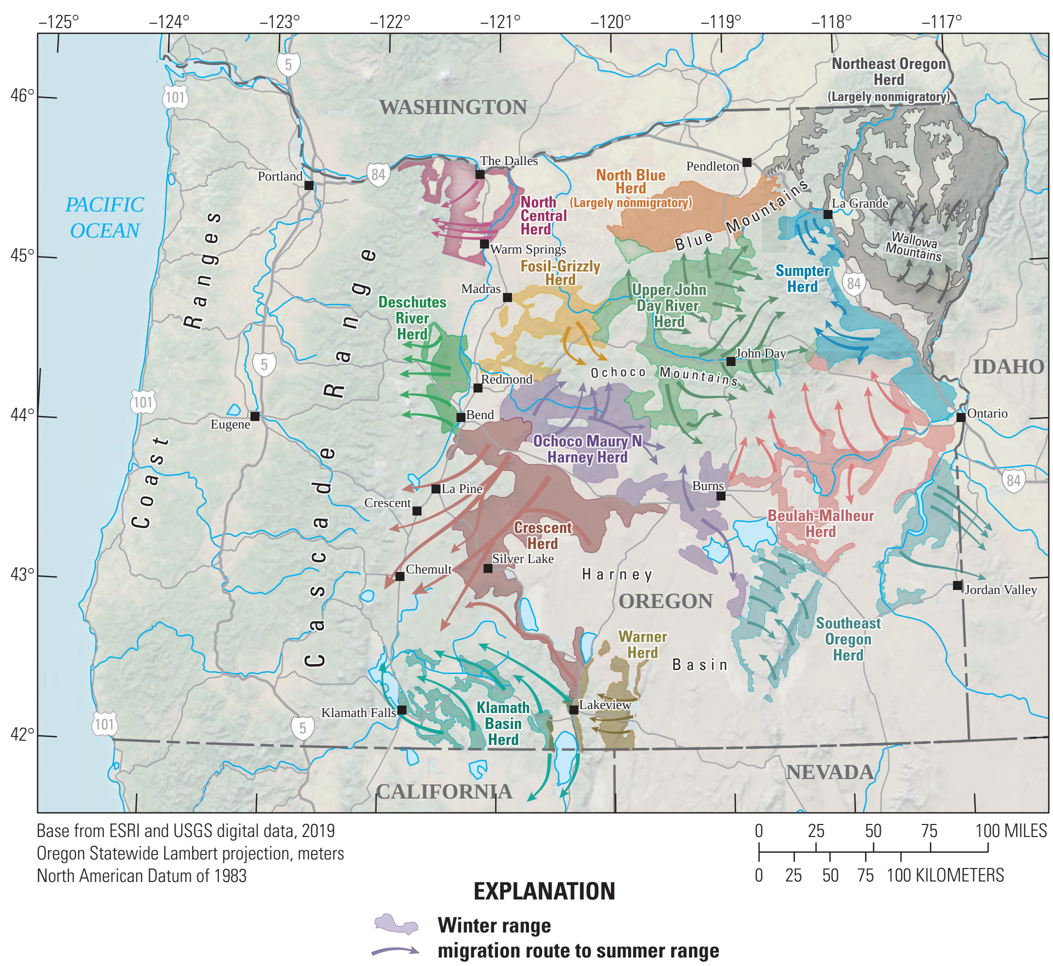

Figure 6. Mule deer migration patterns in Oregon.

Oregon, an area with some of the highest density of mule deer-vehicle collisions in the state. Additionally, these data provide critical information when evaluating development proposals and energy exploration and citing proposals.

In addition to mule deer, Oregon is home to black-tailed deer, which maintain small year-round home ranges and do not migrate. However, preliminary information collected from black-tailed deer in the southern Oregon Cascades using VHF radio collars suggests seasonal ranges may be separated by nearly 35 miles (D.H. Jackson, ODFW, unpublished data). Ongoing work was initiated in 2017 in the area and GPS-collared animals are used to rigorously delineate seasonal ranges and migration routes.

Oregon is working to identify seasonal ranges and migration patterns for pronghorn. Analysis of movement patterns for 50 GPS collared animals between December 2014 and July 2017 (64,020 locations) was completed for the largest population in south-central Oregon using kernel density estimation of migration path segments (Larkins and others, 2018). Preliminary analyses using similar methodology of 53 animals collared with GPS from 2018 through 2020 in central Oregon (approximately 70,000 locations) is nearly complete and will identify any potential movement issues associated with U.S. Highway 20 where it crosses central Oregon. A study encompassing the remainder of the state's primary pronghorn range in southeastern Oregon was initiated in late summer 2019. Analytic methods will be applied to locations from as many as 200 adult pronghorn with GPS collars to identify critical seasonal ranges and movement corridors.

Based on local knowledge and early telemetry studies using VHF collars, *Cervus canadensis nelsoni* (Rocky Mountain elk) in Oregon exhibit extensive movements, both daily and seasonally. However, a detailed description of seasonal ranges, movement patterns, and migration corridors has not been conducted at a landscape level. ODFW initiated work during winter 2019–2020 using GPS collars to address this information need.

Like Rocky Mountain elk, *Cervus canadensis roosevelti* (Roosevelt elk) movements have not been extensively studied in Oregon. The perception, based on small-scale studies using a mix of VHF and GPS technology, suggests Roosevelt elk in Oregon are not as migratory as their Rocky Mountain counterparts. ODFW initiated work in winter 2019–2020 using GPS collars to address this information need.

While work being done throughout the state will aid in identifying migration corridors for many of Oregon's ungulate herds, it is infeasible to delineate discrete migratory pathways for every herd in the state. To ensure consideration of migratory habitat is not limited to corridors identified by deployment of GPS collars, ODFW is also building models to predict migratory habitat connectivity for the state's ungulate populations. As part of the Oregon Connectivity Assessment and Mapping Project, connectivity will be modeled and mapped for mule deer, black-tailed deer, Rocky Mountain elk, and Roosevelt elk, to identify habitats most likely to facilitate movement for each of these species when traveling between seasonal ranges.

Initial modeling of landscape resistance will be completed using known drivers of habitat selection during migration, after migratory connectivity is modeled across each species' range with circuit theory using the Omniscape algorithm (McRae and others, 2016). Both the landscape resistance layer and the migratory connectivity map will be validated using empirical data, to help ensure results can accurately be applied in areas where staff, funding, sample size, or other limitations prevent the delineation of migratory corridors using GPS telemetry. These models, along with corridors identified by tracking GPS-collared animals, will (1) help direct on-the-ground efforts for acquisition, restoration, and conservation of migratory habitat, (2) inform long-term planning of public lands, (3) inform for land-use development, including expansion of urban growth boundaries, permitting for renewable energy development, and development of sensitive habitats, and (4) aid in mitigating transportation issues, including identification of areas where wildlife passage structures could best reduce ungulate-vehicle collisions.

The habitat corridors identified in Oregon, through both GPS telemetry and modeling efforts, will continue to be updated and refined to remain relevant and useful, particularly as improvements are made in studies of land use, disturbances (for example, fire, forest insect, disease outbreaks, and so forth), population demographics, climate change, statistical methods for modeling connectivity, and in measuring uncertainty in connectivity analyses. The ODFW will continue its focus on providing habitat connectivity for the broad array of wildlife species in the state, and the agency will look to its collaborative partnerships with other State, Federal, non-governmental organizations, and nonprofit organizations to help enhance, restore, and protect Oregon's wildlife movement and migration corridors into the future.

This summary was prepared by DeWaine Jackson, Rachel Wheat, and Don Whittaker for the Oregan Department of Fish and Wildlife.

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Utah

The landscape of the western United States is experiencing a period of significant change, as year after year, the region continues to be the one of fastest growing in the country. Utah stands at the heart of this change as one of the fastest growing states (U.S. Census Bureau, 2018). Continued rapid growth is expected, as the state's population is projected to nearly double by 2070 (Perlich, 2017). Rapid change can result in degradation, fragmentation, and in some cases, the complete loss of wildlife habitat (Sawyer and others, 2013). Without careful planning and active mitigation efforts, these changes to Utah's landscape could have real and lasting consequences for wildlife (for example, aquatic, avian, and terrestrial species), some of which may not feasibly be undone in the future.

The Utah Wildlife Migration Initiative (https://wildlifemigration.utah.gov/) was founded by the Utah Division of Wildlife Resources (UDWR) in 2017. The purpose of the initiative is to document, enhance, and preserve wildlife movement to ensure wildlife populations remain productive and healthy as the state grows and moves into the future. State-of-the-art near real-time tracking technology is used to discern landscape-scale spatial movement patterns and survival of Utah's wildlife populations. In 2021, there were more than 2,000 terrestrial animals with GPS tracking devices across the state and plans to deploy another 1,000 collars. There are also thousands of aquatic species that have been tagged and monitored.

The initiative has more 20 million animal locations to describe movement corridors and habitat use across the state. To support data acquisition, foster spatial thinking, and keep up with a rapidly growing database, UDWR adopted a cloud-based solution for managing and using wildlife data. The cloud-based solution developed is capable of storing, processing and sharing big data on wildlife, enabling a more collaborative learning environment for the initiative and its stakeholders. Using Google's analytics platform, tracking data can then be analyzed at high performance and scale with sophisticated modeling techniques producing maps showing where corridors are and how often they are used.

Migration corridors across more than half of the state of Utah have been successfully mapped for mule deer from 2016 to 2020, which includes 1,124 individually collared animals. The mapped corridors provide critical insight into how mule deer move between seasonal habitats and can help identify barriers to their movement. The corridor maps are especially useful for land-use planning, because they highlight areas facilitating movement of large numbers of animals. From local knowledge and early telemetry studies, the initiative is also working to fill the void in areas without collared animals.

The Utah Wildlife Migration Initiative is becoming a powerful force in wildlife conservation in Utah with the support and collaboration of partners. Mapped migration corridors and seasonal home ranges from the wildlife tracking data helped guide habitat restoration efforts, shaping the way wildlife is viewed and managed in Utah.

This summary was prepared by Jessie Shapiro and Daniel Olson for the Utah Division of Wildlife Resources.

Selected Resources

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Washington

Of the 11 western states identified in Secretarial Order 3362 (Department of the Interior, 2018), Washington is the smallest (71,362 square miles), but with 7.7 million residents, the state is second only to California in human population. Results from the 2020 Census indicate Washington's population has increased by 14.6 percent since 2010, and the trend is projected to continue into the foreseeable future (Washington State Office of Financial Management [WSOFM], 2018). As a result, many of the challenges relating to the conservation of Washington's ungulate species are the direct or indirect result of human effects on habitat. These effects include continued expansion of urban and residential development, continued expansion of roadway infrastructure and increased traffic volumes, invasive plant and animal species, conversion of shrub-steppe and grassland habitats to agriculture, the development of solar and wind farms, disease, wildfires, and climate change.

The Washington Department of Fish and Wildlife (WDFW) is actively involved in several efforts related to conserving migration corridors and addressing habitat connectivity issues. The Interstate 90 Snoqualmie Pass East Wildlife and Habitat Connectivity Project has been a model of successful interdisciplinary collaboration between WDFW, the Washington State Department of Transportation (WSDOT), USFS, USFWS, nongovernment organizations, and the general public. The project seeks to restore connectivity between the southern and northern ranges of the Cascade mountains bisected by Interstate 90. When this project is complete, it will involve more than 30 distinct wildlife crossing structures of various sizes, from small underpasses designed for low-mobility species, to structures which span more than 1,000 feet and facilitate safe passage for larger animals.

Washington also achieved positive outcomes with projects on a much smaller scale. In Goldendale, Washington, a recent highway underpass replacement was designed to allow passage not only for the underlying stream, but also for mule deer and other large wildlife. With the relatively simple addition of a few extra feet on either side of the stream and fencing to direct wildlife passage underneath the bridge, the project resulted in an 81 percent decrease in wildlife-vehicle collisions (ARC Solutions, 2020).

The Washington Wildlife Habitat Connectivity Working Group (WHCWG), formed in 2007 between WSDOT and WDFW, is an open collaborative science-based effort producing tools and analyses identifying opportunities and priorities for maintaining habitat connectivity in Washington. While these efforts have not focused specifically on wildlife migration corridors and winter range, they have contributed to structured, scientifically based advancements related to preserving habitat connectivity for many species, including mule deer and elk (WHCWG, 2012).

Despite these efforts, large information gaps remain relative to identifying important migration corridors and winter use areas for Washington's native ungulate species, which includes black-tailed deer, mule deer, white-tailed deer, elk, moose, bighorn sheep, mountain goats, and pronghorn. Although all these species exhibit migration patterns at some level, the most prominent seasonal movements are associated with elk, black-tailed deer, and mule deer living along the eastern and western slopes of the Cascade Range. Many of these herds migrate from high alpine meadows and forests to lower elevation valleys for the winter. The one exception to this pattern is a westerly migration of mule deer from eastern Washington to core winter ranges in the Columbia Plateau.

Seasonal migration occurs with many mule deer populations in eastern Washington, but little work has been done to better understand their movement patterns and to identify important migration corridors. The WDFW manages mule deer within seven management zones, each represent a distinct ecoregion within the state (Omernik, 1987; WDFW, 2016). Previous research efforts estimated survival and nutritional status within several management zones, but movement data were limited because of technological and budgetary constraints and are insufficient for modern spatial analyses. The only region where WDFW data were available to conduct robust spatial analyses of GPS-collar data (for example, Brownian bridge movement models; Sawyer and others, 2009) was in the northern part of the eastern slope of the Cascade Range (see Washington mule deer section of this report). Consequently, WDFW prioritized mule deer in the Washington State Wildlife Action Plan and identified three zones, including the arid but heavily cultivated shrubsteppe of the Columbia Plateau, the remote high-alpine meadows of the East Slope Cascades (as defined in the Washington State Wildlife Action Plan; Washington Department of Fish and Wildlife, 2015), and the oak-dominated forests in the East Columbia Gorge.

With funding secured through Secretarial Order 3362 (Department of the Interior, 2018), WDFW captured and marked 98 adult female mule deer with GPS radio-collars in southern part of the East Slope Cascades zone (as defined in the Washington State Wildlife Action Plan; Washington Department of Fish and Wildlife, 2015) in 2020 and an additional 80 adult female mule deer in the East Columbia Gorge zone in 2021. Information gathered from radio-collars will enable WDFW to identify important corridors and stopover locations for mule deer within these management zones while also identifying any barriers (for example, fences, roads, developments, and so forth) impeding movements. More broadly, these data will allow WDFW to better identify habitat conservation needs and to communicate more effectively with stakeholders regarding the importance of conserving these landscapes for the benefit of mule deer.

WDFW also partnered with USFWS, Pheasants Forever, and the Mule Deer Foundation to secure $926,000 through Secretarial Order 3362 (Department of the Interior, 2018) to fund habitat conservation and restoration projects that will benefit mule deer in Washington.

Although these initial monitoring efforts will provide important information for the conservation of mule deer in Washington, much more work needs to be done, and WDFW remains committed to collaborating with our conservation partners to identify and protect important migration corridors into the future.

This summary was prepared by Brock Hoenes and Elizabeth Torrey for the Washington Department of Fish and Wildlife.

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Wyoming

Wyoming has vast landscapes of intact wildlife habitat in large part because of the state's relatively small human population. However, in recent years an increasing footprint of disturbance from suburban expansion, energy development, and habitat conversion because of invasive species presented challenges to maintaining ungulate migrations in the state. Although Wyoming has some of the longest migrations recorded in the conterminous United States (up to 242 miles [389 km]), it also has shorter-distance migrations (approximately 5–10 miles) equally important to allow animals to reach key seasonal ranges. Wyoming Game and Fish Department (WGFD) has been engaged with studying migratory movements of ungulates for decades, including through the era of visibility collars, VHF collars, and most recently the extensive use of GPS collars. Advancements in GPS technology and new analytical techniques have dramatically improved our understanding of migratory movements, which has allowed wildlife managers to refine strategies to better manage ungulate populations across the state. In 2016, the Wyoming Game and Fish Commission (WGFC) enacted the Ungulate Migration Corridor Strategy, which directed the WGFD to use science and data to prioritize actions that would maintain distribution and abundance of migrating populations. This State policy also provided guidance on land-use recommendations and asserted the importance of public outreach and risk assessments for priority herds in the state. Through the direction of the Ungulate Migration Corridor Strategy, the WGFD designated the Sublette, Platte Valley and Baggs mule deer migration corridors as vital habitat, and significant effort has been put into implementing conservation practices on the ground within these corridors.

In 2019, Governor Mark Gordon appointed a Wildlife Migration Advisory Group, which included diverse stakeholders who were asked to develop recommendations to ensure ungulate migrations persist while continuing to build strong energy and agriculture industries in Wyoming. The most significant outcome of this effort was the enactment of Executive Order 2020-1, the Wyoming Mule Deer and Antelope Migration Corridor Protection Executive Order (Wyoming Office of the Governor, 2020). This executive order reaffirms designation of the previous three existing corridors (Sublette, Platte Valley, and Baggs mule deer migration corridors) and directs how development and disturbances should be managed to ensure functionality of the migration corridors into the future. The executive order also outlines a process to engage the public in future efforts to identify corridors having potential to lead to eventual formal designation by the Governor.

Working with funding partners, private landowners, and Federal land managers to implement conservation actions is an important priority for Wyoming. Funding opportunities from 2018 to 2021 associated with the Secretarial Order 3362 (Department of the Interior, 2018) have resulted in funding of $1,753,000 and $596,500 from the National Fish and Wildlife Foundation and the USFWS Partners for Fish and Wildlife respectively, which were incorporated into habitat management programs specifically associated with migratory big game herds. These funds have primarily targeted invasive species and cheatgrass treatments, fence modifications, and aspen and juniper enhancements in five priority herds. In 2018, The Nature Conservancy of Wyoming led an effort to successfully secure $5,000,000 from the Resource Conservation Partnership Program with the Natural Resources Conservation Service to implement on-the-ground activities benefitting ungulate migration, including conservation easements, fence modifications, and invasive species control. This was further expanded in 2021, with an additional $6,400,000 secured to continue this program for another three years. Additionally, significant effort has been put into wildlife crossing projects working in collaboration with the Wyoming Department of Transportation. These projects have included a wide variety of solutions, including variable message signs, right-of-way (ROW) mowing, ROW fence modifications, and in some cases large-scale projects such as construction of underpasses and overpasses with associated wildlife-proof fencing.

Data collection and research efforts of the WGFD have been significantly enhanced by $600,000 provided by DOI in 2018 and 2019 to implement GPS collar studies in seven different mule deer and pronghorn herds across Wyoming. The State places a high value on the collection of robust GPS collar data to advance the understanding of migratory movements and assist with prioritizing conservation on the ground. Longstanding partnerships with USGS, the Wyoming Migration Initiative, and the University of Wyoming have been essential to improve the overall scope and scientific analyses associated with our GPS collar projects across the state.

This summary was prepared by Jill Randall for the WGFD.

Selected Resources

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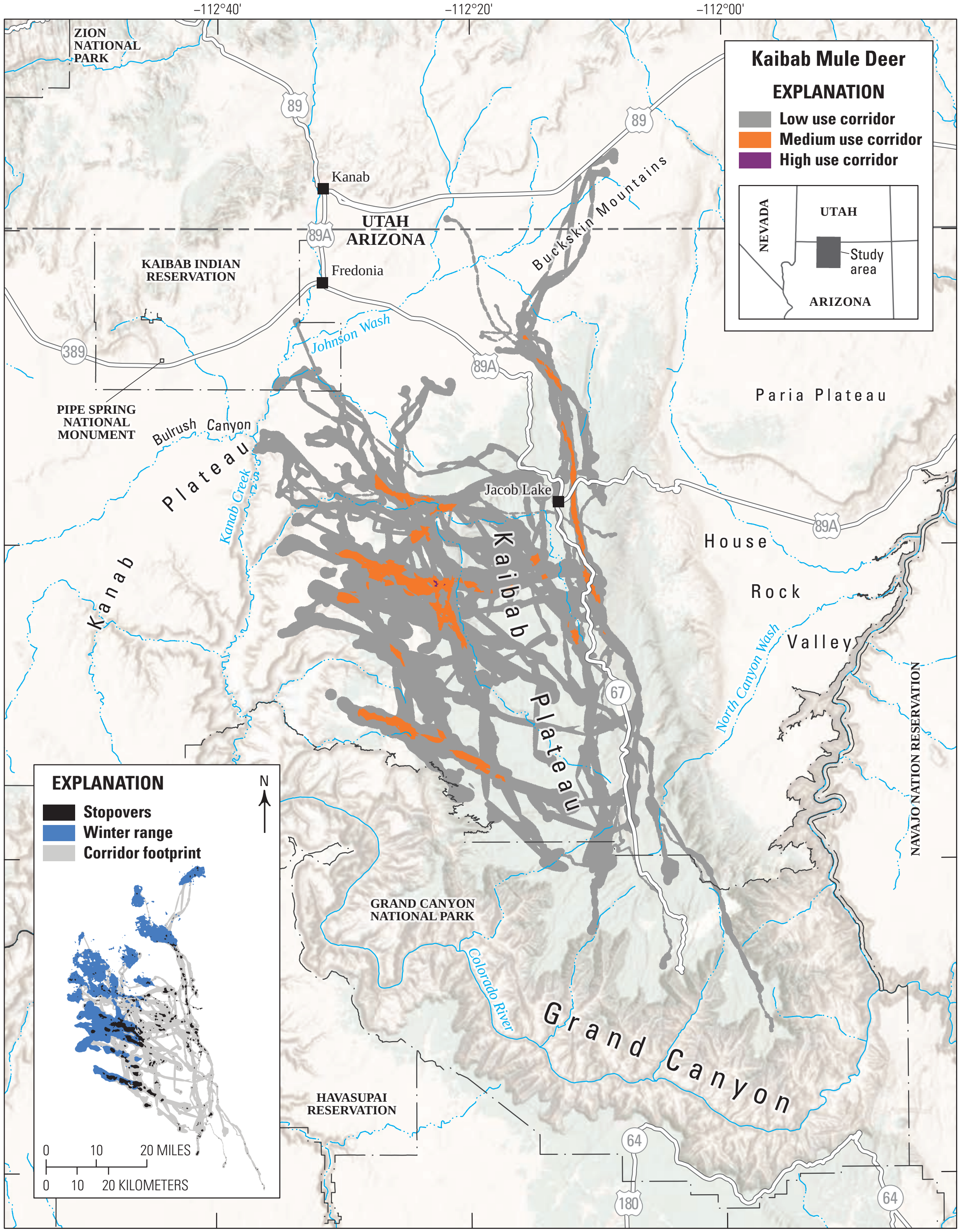
Herd Summaries

The herd-specific maps and associated summary text provide the core of the Ungulate Migrations of the Western United States report series. In the sections that follow, we provide maps documenting 65 migrations within 9 western states and select Tribal lands. These maps have been produced in close collaboration with participating State or Tribal agencies, who have collected the GPS collar data in most cases. The respective habitat areas for each state vary based on state-level policies and may include migration routes (lines) or corridors (polygons), stopovers, winter ranges, or annual ranges. In combination with the associated text, these page pairs provide an overview of the documented ungulate migrations across the western United States and serve as an additional tool to help inform local and regional management and conservation. The data layers for many of the herds mapped in this section are also available to the general public through the associated data release (Kauffman and others, 2022).



Base from ESRI and U.S. Geological Survey digital data, 2019
Universal Transverse Mercator projection, zone 12N
North American Datum of 1983

Figure 7. Migration corridors, stopovers, and winter ranges of the Kaibab mule deer herd.

Arizona | Mule Deer

Kaibab Mule Deer

Mule deer of the Kaibab Plateau in Arizona had a population estimate of 10,200 individuals in 2019. The Kaibab mule deer herd is relatively isolated, limited in range to the east, south, and west sides by the Grand Canyon and Kanab Creek (fig. 7). Annually the Kaibab herd migrates an average of 27 mi (43 km) between summer and winter ranges. The winter range is along the west, east, and northern extents of the plateau; consisting of pinyon-juniper woodlands mixed with sagebrush, cliffrose, bitterbrush, and various grasses. Some of the Kaibab herd winters in Utah, sharing winter range with the Utah Paunsaugunt Plateau herd. During migration, mule deer pass through midelevation transitional range containing Gambel oak, pinyon pine, and Utah juniper. Summer range is dominated by a mix of ponderosa pine, spruce, fir, and aspen, interspersed with open meadows. There are currently few impediments to mule deer migration on the Kaibab Plateau.

Animal Capture and Data Collection

Sample size: 48 mule deer (13 male, 35 female)
Relocation frequency: 30 minutes–7 hours
Project duration: 2012–2014 (Arizona study); 2017–present (Utah study)

Data Analysis

Corridor, stopover, and winter range analysis: Brownian bridge movement models (Sawyer and others, 2009); corridor analysis used Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from

- Migration: 123 sequences from 48 individuals (67 spring sequences, 56 fall sequences)
- Winter: 80 sequences from 44 individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: April 21 to May 3
- Fall: October 29 to November 12

Average number of days migrating:

- Spring: 13 days
- Fall: 18 days

Migration corridor length:

- Minimum: 9 mi (14 km)
- Mean: 27 mi (43 km)
- Maximum: 100 mi (161 km)

Migration corridor area:

- 293,135 acres (118,630 hectares [ha]) (low use)
- 139,760 acres (56,560 ha) (medium use)
- 49 acres (20 ha) (high use)
- Stopover area: 29,949 acres (12,120 ha)

Winter Range Summary

Winter start and end dates (median):

- November 13 to April 21
- Winter length (mean): 148 days
- Winter range (50 percent contour) area: 141,910 acres (57,430 ha)

Other Information

Project contacts:

- Jeff Gagnon (jgagnon@azgfd.gov), Wildlife Specialist Regional Supervisor, Arizona Game and Fish Department
- Daniel Olson (danielolson@utah.gov), Wildlife Migration Initiative Coordinator, Utah Department of Natural Resources

Data analyst:

- Lucas Olson, Cooperative Mule Deer Biologist, Mule Deer Foundation and Arizona Game and Fish Department

Reports and publications:

- Bristow, K., Harding, L., Lucas, R., and McCall, T., 2020, Influence of fire severity and vegetation treatments on mule deer (*Odocoileus hemionus*) winter habitat use on the Kaibab Plateau, Arizona: Animal Production Science, v. 60, p. 118–125. [Also available at https://10.1071/AN19373.]
- Carrel, W.K., Ockenfels, R.A., and Schweinsburg, R.E., 1999, An evaluation of annual migration patterns of the Paunsaugunt mule deer herd between Utah and Arizona: Phoenix, Ariz., Arizona Game and Fish Department, 44 p.
- Russo, J.P., 1964, The Kaibab North deer herd: Phoenix, Arizona, Game and Fish Department, 195 p.

Photograph from George Andrejko, Arizona Game and Fish Department.

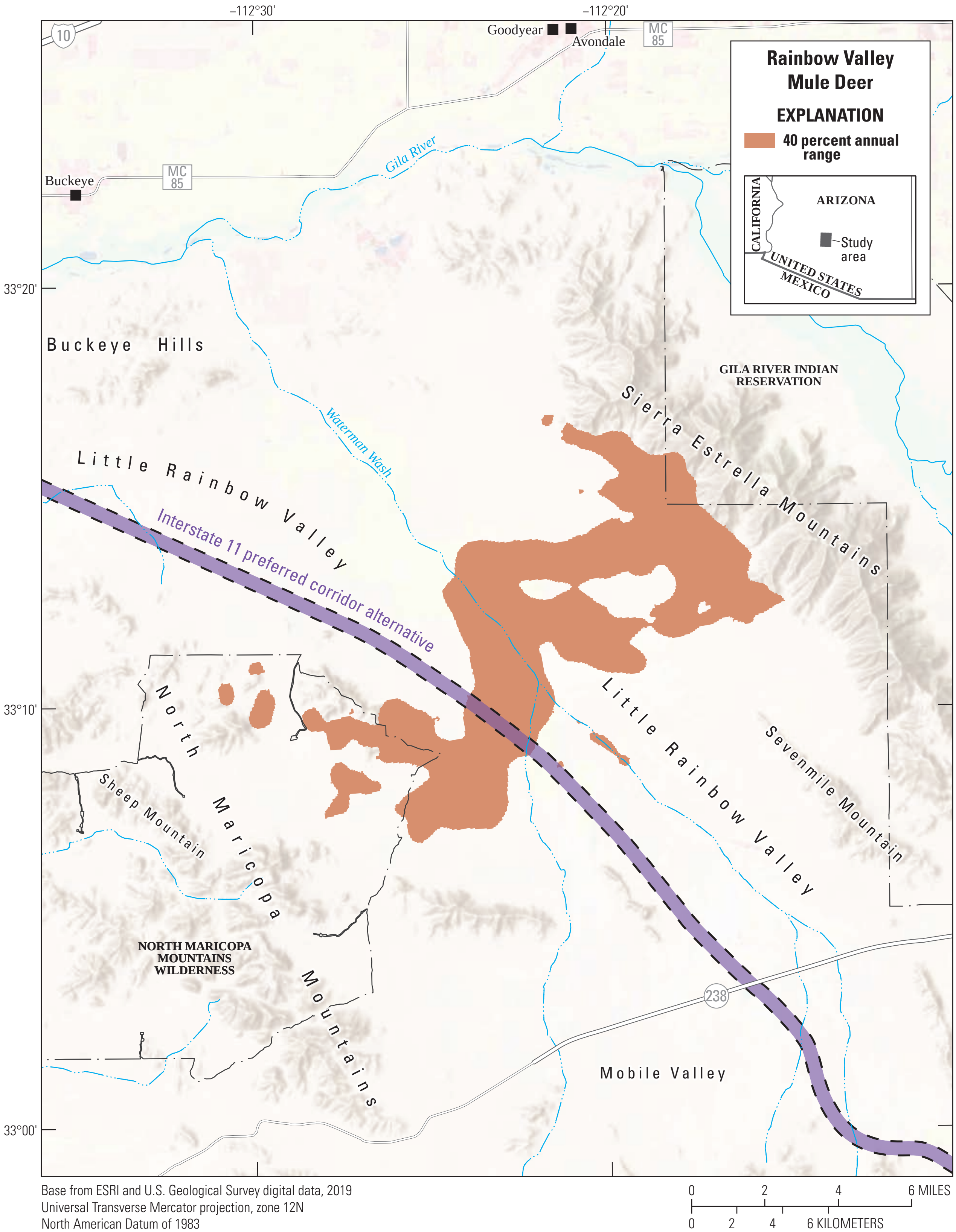


Figure 8. Annual range of the Rainbow Valley mule deer herd.

Arizona | Mule Deer

Rainbow Valley Mule Deer

The Rainbow Valley mule deer reside in the expansive Sonoran Desert flat between the Sierra Estrella Mountains and the North Maricopa Mountains (fig. 8). The herd, which numbered 1,500 in 2017, is managed within GMU 39 and 40. The movements depicted in this report represent annual range for three mule deer, which are part of a much larger research project along the Interstate 11 preferred corridor alternative. The research is conducted by the Arizona Game and Fish Department (AZGFD), with funding from the DOI through Secretarial Order 3362 (Department of the Interior, 2018). Although the Rainbow Valley mule deer are not migratory in the traditional sense, their annual patterns show substantial 15–20 mi movements throughout this desert valley. These movements likely occur in response to seasonally variable food and water sources. AZGFD recognizes the potential for future research and conservation opportunities across the landscapes traversed by the entire Interstate 11 study area. For example, understanding mule deer movement pathways will be essential in the effort to avoid, minimize, and mitigate effects of Interstate 11, if it is constructed. AZGFD is a Cooperating Agency for the Arizona Department of Transportation (ADOT) tiered impact study for Interstate 11 and has been working to understand the potential effects the proposed Interstate 11 highway would have on wildlife, if constructed. The timelines associated with ongoing movement studies and road design will allow AZGFD to analyze data, and provide ADOT with robust input on corridor routes to aid in the design of specific mitigation measures and improvements for wildlife connectivity.

Animal Capture and Data Collection

Sample size: 3 adult female mule deer
Relocation frequency: 3 hours
Project duration: 2019–present

Data Analysis

Annual range analysis: Brownian bridge movement models (Horne and others, 2007; see app. 1 for further description)

Models derived from:

- Annual range: 6 sequences from 3 individuals

Annual Use Summary

- Annual range (40 percent contour) area: 29,281 acres (11,850 ha)
- Corridor length
- Mean: 15 mi (24 km)

Other Information

Project contacts:

- Jeff Gagnon (jgagnon@azgfd.gov), Wildlife Specialist Regional Supervisor, Arizona Game and Fish Department
- Scott Sprague (ssprague@azgfd.gov), Project Manager/Road Ecologist, Arizona Game and Fish Department

Data analyst:

- Lucas Olson, Cooperative Mule Deer Biologist, Mule Deer Foundation and Arizona Game and Fish Department

Photograph from Thomas Bommarito, Bureau of Reclamation.

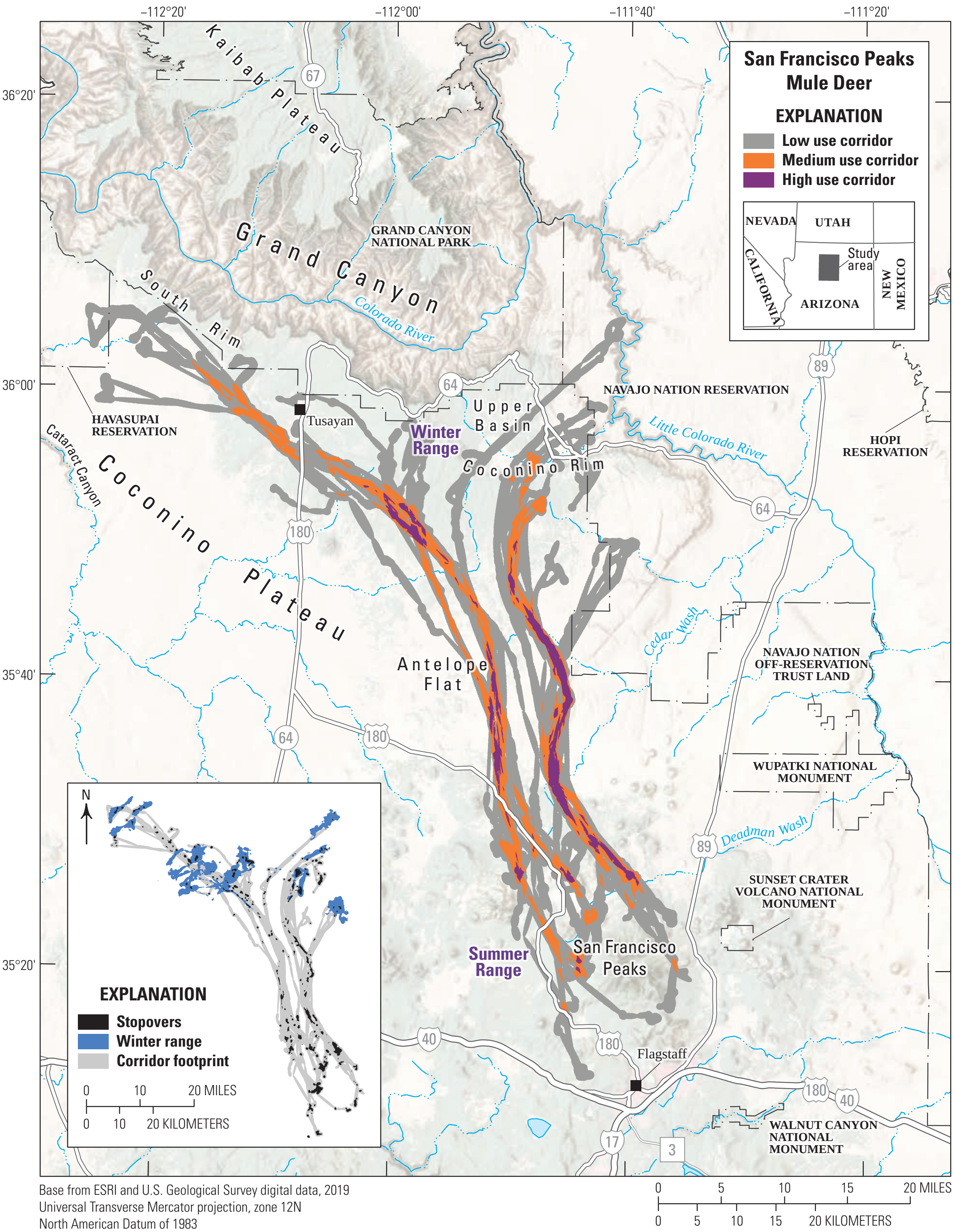


Figure 9. Migration corridors, stopovers, and winter ranges of the San Francisco Peaks mule deer herd.

Arizona | Mule Deer

San Francisco Peaks Mule Deer

The San Francisco Peaks mule deer herd makes one of Arizona's most extraordinary annual migrations between Flagstaff and the Grand Canyon (fig. 9). The migration begins on summer range in GMU 7, where an estimated 5,300 mule deer reside. Their summer habitat contains alpine, subalpine, and ponderosa pine forests mixed with open grasslands and meadows. Beginning in October, a portion of the herd migrates north to GMU 9 to winter range along the South Rim containing pinyon-juniper, ponderosa pines, sagebrush, and cliffrose habitat. Through funding from Secretarial Order 3362 (Department of the Interior, 2018), the AZGFD began a GPS collar study beginning in June 2019. A total of 46 mule deer have been tracked during this study, which will be completed in 2023. In contrast to the volume 1 report (Kauffman and others, 2020a), the San Francisco Peaks mule deer herd in this volume 2 report contains an additional 20 mule deer, 52 migrations, and 12 winter sequences. The primary challenges to mule deer in this migration corridor are related to navigating highways. These mule deer must traverse two major highways, U.S. Highway 180 and State Route 64, which experience high traffic volumes and are a source of mortality.

Animal Capture and Data Collection

Sample size: 29 adult mule deer (3 males, 26 females)
Relocation frequency: Approximately 2–3 hours
Project duration: 2008–2009 and 2019–present

Data Analysis

Corridor, stopover, and winter range analysis: Brownian bridge movement models (Sawyer and others, 2009); corridor analysis used Fixed Motion Variance (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 58 sequences from 24 individuals (24 spring sequences, 34 fall sequences)
- Winter: 21 sequences from 20 individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: April 5 to April 24
- Fall: October 24 to October 28

Days migrating:

- Spring: 11 days
- Fall: 5 days

Migration corridor length:

- Minimum: 32 mi (51 km)
- Mean: 50 mi (80 km)
- Maximum: 80 mi (129 km)

Migration corridor area:

- 272,452 acres (110,257 ha) (low use)
- 63,702 acres (25,779 ha) (medium use)
- 6,012 acres (6,478 ha) (high use)
- Stopover area: 27,675 acres (11,110 ha)

Winter Range Summary

Winter start and end dates (median):

- October 28 to April 5
- Winter length (mean): 153 days
- Winter range (50 percent contour) area: 68,496 acres (27,719 ha)

Other Information

Project contacts:

- Jeff Gagnon (jgagnon@azgfd.gov), Wildlife Specialist Regional Supervisor, Arizona Game and Fish Department
- Scott Sprague (ssprague@azgfd.gov), Project Manager/ Road Ecologist, Arizona Game and Fish Department

Data analyst:

- Lucas Olson, Cooperative Mule Deer Biologist, Mule Deer Foundation and Arizona Game and Fish Department

Reports and publications:

- Dodd, N.L., Gagnon, J.W., Sprague, S.C., Boe, S., and Schweinsburg, R.E., 2012, Wildlife accident reduction study and monitoring—Arizona State Route 64: Phoenix, Ariz., Arizona Department of Transportation Research Center, Final project report 626, 118 p. [Also available at https://arc-solutions.org/wp-content/uploads/2013/02/AZ626-Wildlife-Accident-Reduction-Study-Monitoring-Az-State-Route-64.pdf.]

Photograph from George Andrejko, Arizona Game and Fish Department.

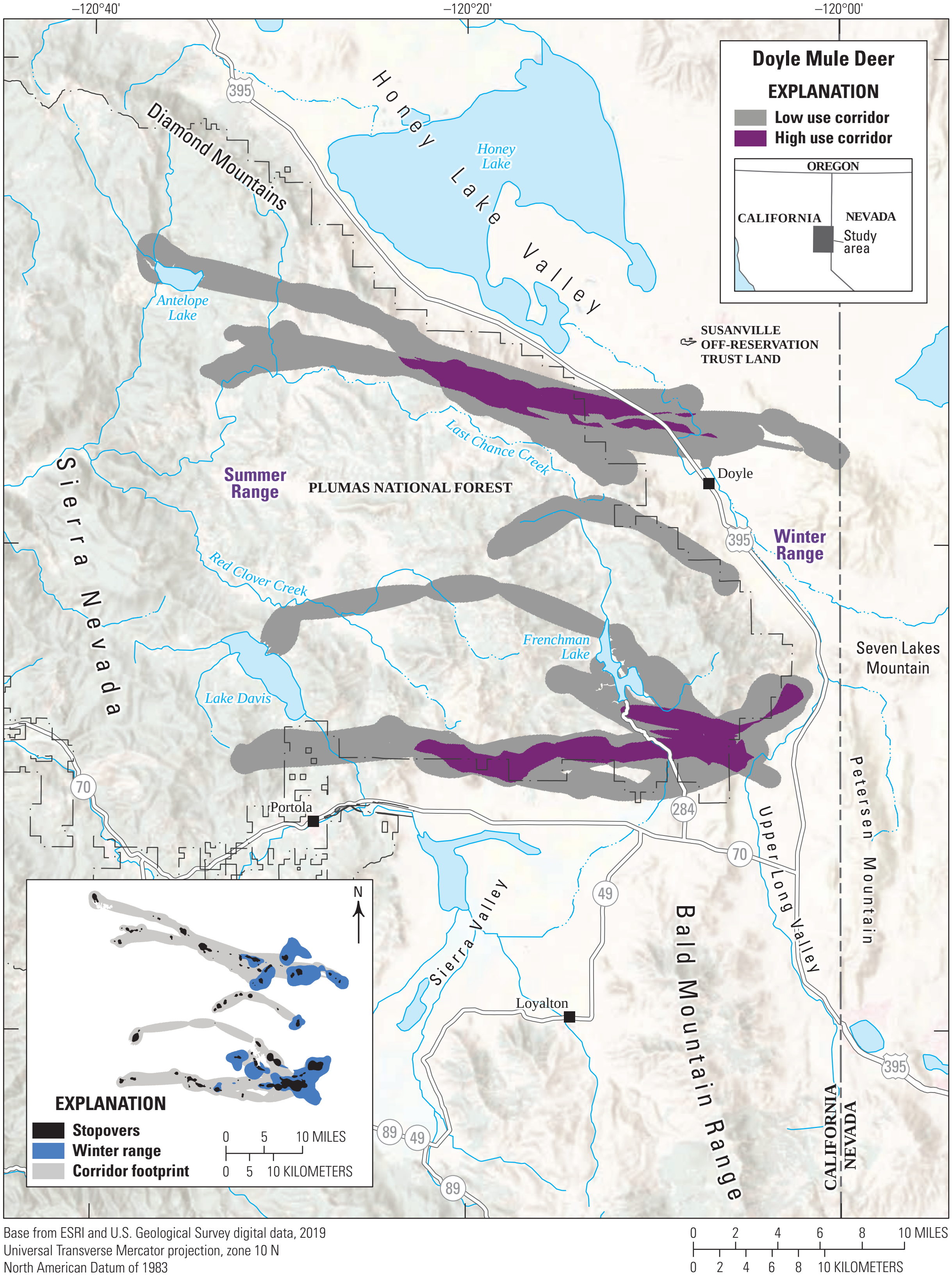


Figure 10. Migration corridors, stopovers, and winter ranges of the Doyle mule deer herd.

California | Mule Deer

Doyle Mule Deer

The Doyle mule deer herd migrates from a winter range in Honey Lake Valley and Upper Long Valley near Doyle, California, along U.S. Highway 395 in Lassen County, California, and eastward into Plumas County and Plumas National Forest in the Sierra Nevada for the summer (fig. 10). The winter range also exists on the Nevada side of the stateline in Washoe County. Much of the winter range habitat is now deteriorated because of extensive wildfires and development along U.S. Highway 395 and lacks vegetation historically providing forage. U.S. Highway 395 is a major barrier to migration, with hundreds of mule deer killed annually. Population estimates were approximately15,600 in 2019.

Animal Capture and Data Collection

Sample size: 25 adult female mule deer
Relocation frequency: 3–13 hours
Project duration: 2016–2019

Data Analysis

Corridor, stopover, and winter range analysis: Brownian bridge movement models (Sawyer and others, 2009); corridor analysis used Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 44 sequences from 14 individuals (20 spring sequences, 24 fall sequences)
- Winter: 25 sequences from 14 individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: April 15 to April 23
- Fall: October 20 to October 26

Average number of days migrating:

- Spring: 8 days
- Fall: 6 days

Migration route length:

- Minimum: 1.73 mi (2.78 km)
- Mean: 17.01 mi (27.38 km)
- Maximum: 29.13 mi (46.88 km)

Migration corridor area:

- 136,004 acres (55,039 ha) (low use)
- 23,944 acres (9,690 ha) (high use)
- Stopover area: 14,702 acres (5,950 ha)

Winter Range Summary

Annual range (40 percent contour) area:

- October 27 to April 16
- Winter use length (mean): 153 days
- Winter range (50 percent contour) area: 48,407 acres (19,590 ha)

Other Information

Project contacts:

- Julie Garcia (Julie.garcia@wildlife.ca.gov), Deer Biologist, California Department of Fish and Wildlife
- Brian Ehler (Brian.Ehler@wildlife.ca.gov), Unit Wildlife Biologist, California Department of Fish and Wildlife
- Stacy Anderson (Stacy.Anderson@wildlife.ca.gov), Unit Wildlife Biologist, California Department of Fish and Wildlife

Data analyst:

- Evan Greenspan, Senior GIS Analyst, California Department of Fish and Wildlife

Photograph from California Department of Fish and Wildlife.

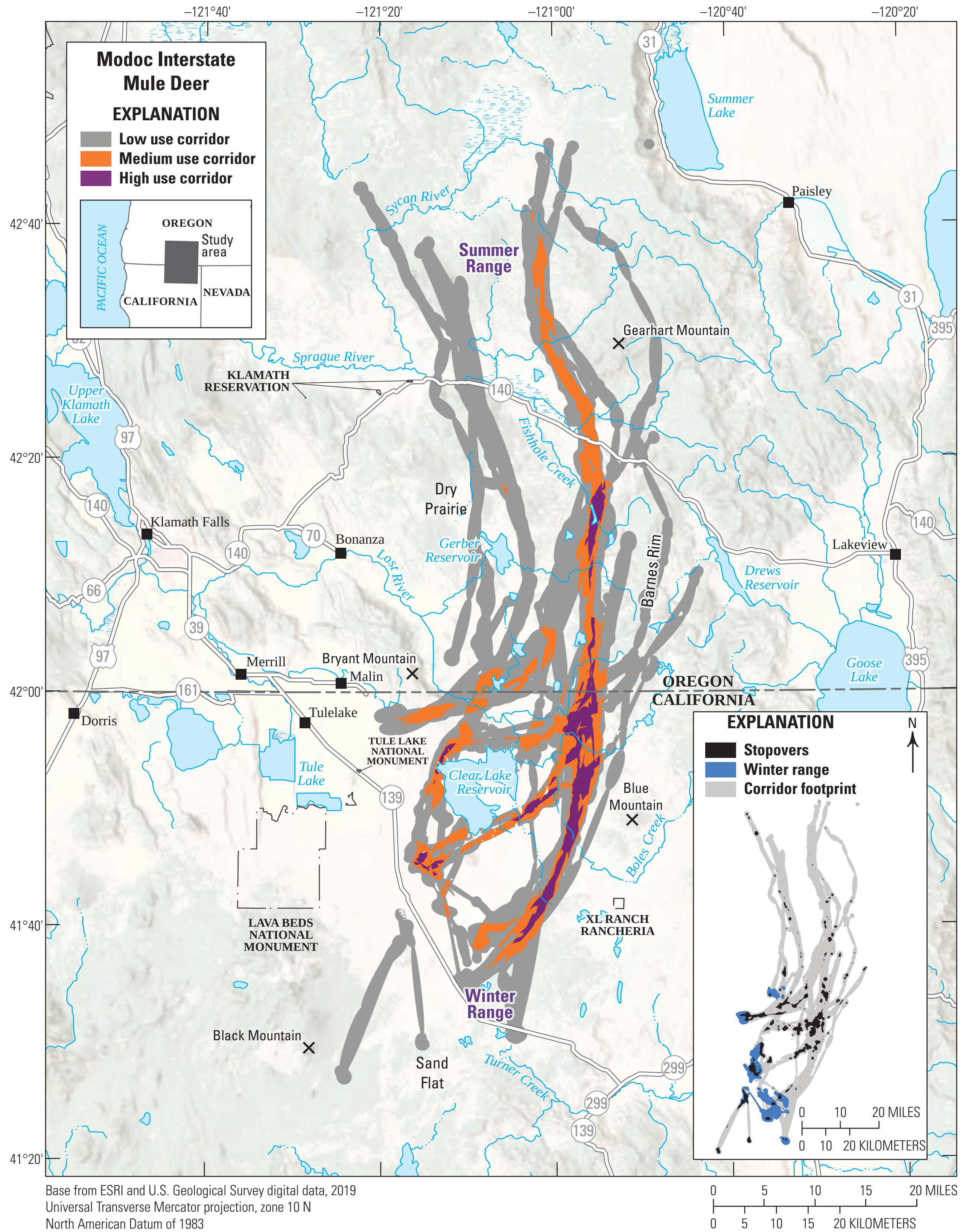


Figure 11. Migration corridors, stopovers, and winter ranges of the Modoc Interstate mule deer herd.

California | Mule Deer

Modoc Interstate Mule Deer

The Modoc Interstate mule deer herd migrates from a winter range near Clear Lake Reservoir in Modoc County, California north into Oregon in Klamath and Lake Counties for the summer (fig. 11). Much of this herd likely resides in Oregon year round as California population estimates (2,000–3,000) are lower than Oregon estimates (approximately 15,000). Female mule deer were captured in Modoc County in February 2017 and equipped with satellite collars manufactured by Lotek. Additional GPS data were collected between 1999 and 2001 from mule deer captured in 1999 and were included to supplement the small sample size of the 2017–2020 dataset. The data were collected with a priority to ascertain general distributions, survival, and home range, and not to model migration routes, hence the low sample sizes. Threats to this herd include increased fire frequency and conversion to non-native annual grass. Moreover, increased distribution of juniper woodlands resulted in a loss of forbs, grass, and shrubs.

Animal Capture and Data Collection

Sample size: 10 adult male mule deer, 75 adult female mule deer

Relocation frequency: 8–12 hours

Project duration: 1999–2001, 2017–2020

Data Analysis

Corridor, stopover, and winter range analysis: Brownian bridge movement models (Sawyer and others, 2009); corridor analysis used Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 52 sequences from 21 individuals (33 spring sequences, 19 fall sequences)
- Winter: 32 sequences from 20 individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: April 1 to May 1
- Fall: October 12 to October 24

Average number of days migrating

- Spring: 27 days
- Fall: 10 days

Migration corridor length

- Minimum: 13.57 mi (21.84 km)
- Mean: 51.00 mi (82.08 km)
- Maximum: 83.08 mi (133.70 km)

Migration corridor area

- 548,710 acres (222,055 ha) (low use)
- 122,166 acres (49,439 ha) (medium use)
- 29,257 acres (11,840 ha) (high use)
- Stopover area: 57,253 acres (23,169 ha)

Winter Range Summary

Winter start and end dates (median):

- October 24 to April 2
- Winter length (mean): 163 days
- Winter range (50 percent contour) area: 69,040 acres (27,940 ha)

Other Information

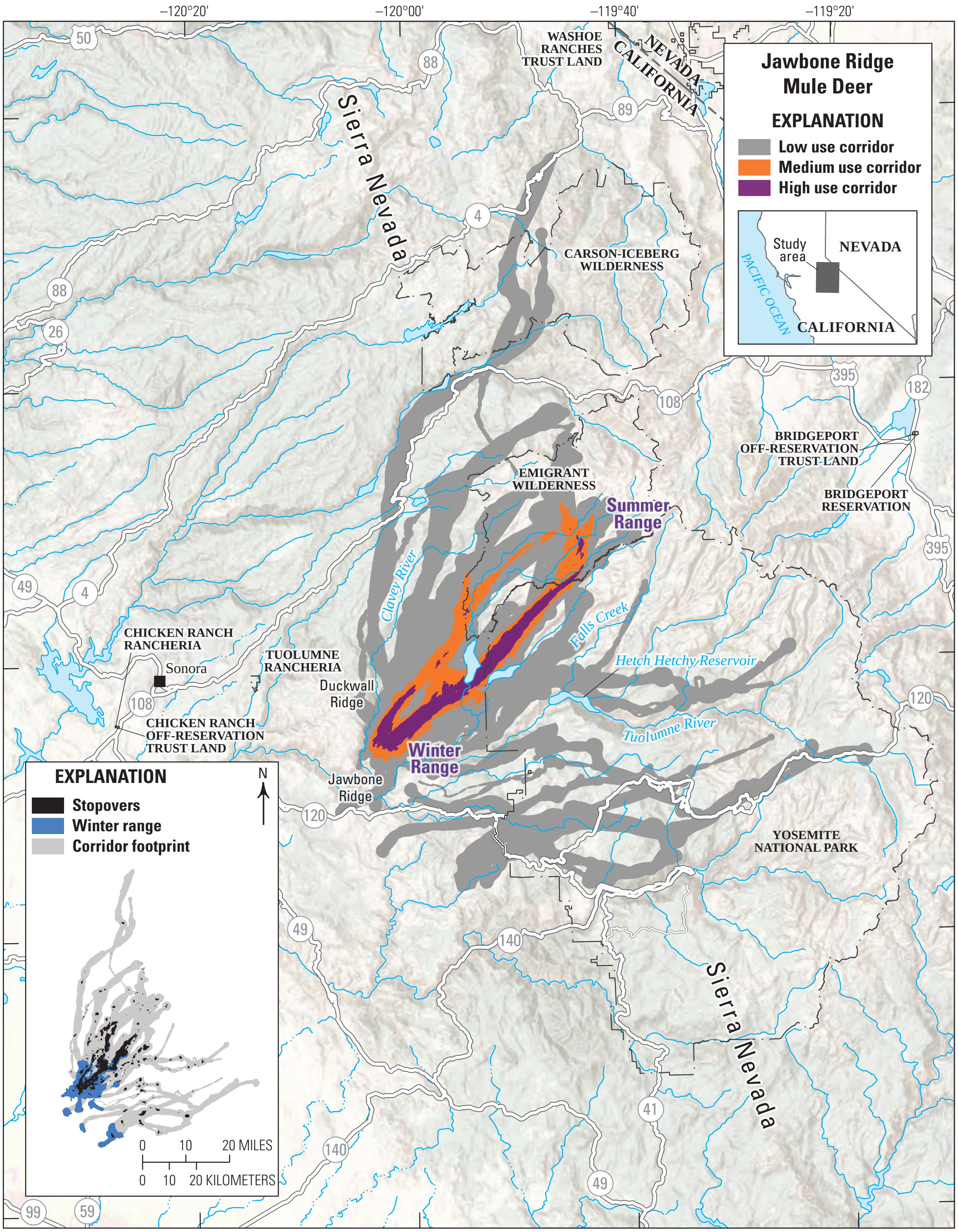
Project contacts:

- Julie Garcia (Julie.garcia@wildlife.ca.gov), Deer Biologist, California Department of Fish and Wildlife
- Richard Shinn (Richard.shinn@wildlife.ca.gov), Environmental Scientist, California Department of Fish and Wildlife

Data analyst:

- Evan Greenspan, Senior GIS Analyst, California Department of Fish and Wildlife

Photograph from California Department of Fish and Wildlife.



Base from ESRI and U.S. Geological Survey digital data, 2019
Universal Transverse Mercator projection, zone 11N
North American Datum of 1983

0 5 10 15 20 MILES
0 5 10 15 20 KILOMETERS

Figure 12. Migration corridors, stopovers, and winter ranges of the Jawbone Ridge mule deer herd.

California | Mule Deer

Jawbone Ridge Mule Deer

The Jawbone Ridge mule deer herd, a subherd of the Tuolumne herd, inhabits portions of Tuolumne, Mariposa, and Alpine Counties, California in the Sierra Nevada (fig. 12). Jawbone Ridge and adjacent winter range habitat was further divided into the Clavey and Cherry subherd units (Leopold and others, 1951). Additionally, a small sample of mule deer was captured from the Yosemite herd (south of Jawbone Ridge) to determine herd overlap. The Clavey and Cherry subherd units support the highest concentration of wintering mule deer within the Tuolumne mule deer herd range. The majority of mule deer in these subherds migrate east into the Emigrant and Yosemite Wilderness for the summer, with some heading north to the Carson-Iceberg Wilderness. Low density populations of nonmigratory mule deer are present in the winter range. Forest practices, wildfires, and recreation (for example, hunting, camping, and off-highway vehicle) represent the most significant effects to this herd.

Animal Capture and Data Collection

Sample size: 97 female mule deer
Relocation frequency: 1–7 hours
Project duration: 2009–2016

Data Analysis

Corridor, stopover, and winter range analysis: Brownian bridge movement models (Sawyer and others, 2009); corridor analysis used Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 245 sequences from 83 individuals (132 spring sequences, 113 fall sequences)
- Winter: 185 sequences from 85 individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: April 27 to May 27
- Fall: October 4 to November 10

Average number of days migrating:

- Spring: 30 days
- Fall: 33 days

Migration corridor length:

- Minimum: 13.57 mi (21.84 km)
- Mean: 51.00 mi (82.08 km)
- Maximum: 83.08 mi (133.70 km)

Migration corridor area:

- 414,058 acres (167,563 ha) (low use)
- 50,631 acres (20,490 ha) (medium use)
- 18,162 acres (7,350 ha) (high use)
- Stopover area: 43,486 acres (17,598 ha)

Winter Range Summary

Winter start and end dates (median):

- November 10 to April 27
- Winter length (mean): 165 days
- Winter range (50 percent contour) area: 69,040 acres (27,940 ha)

Other Information

Project contacts:

- Julie Garcia (Julie.garcia@wildlife.ca.gov), Deer Biologist, California Department of Fish and Wildlife
- Nathan Graveline (Nathan.Graveline@wildlife.ca.gov), Senior Environmental Scientist, California Department of Fish and Wildlife
- Ronald Anderson (ronald.i.anderson@usda.gov), United States Department of Agriculture, Animal Plant and Health Inspection Service, and Wildlife Services

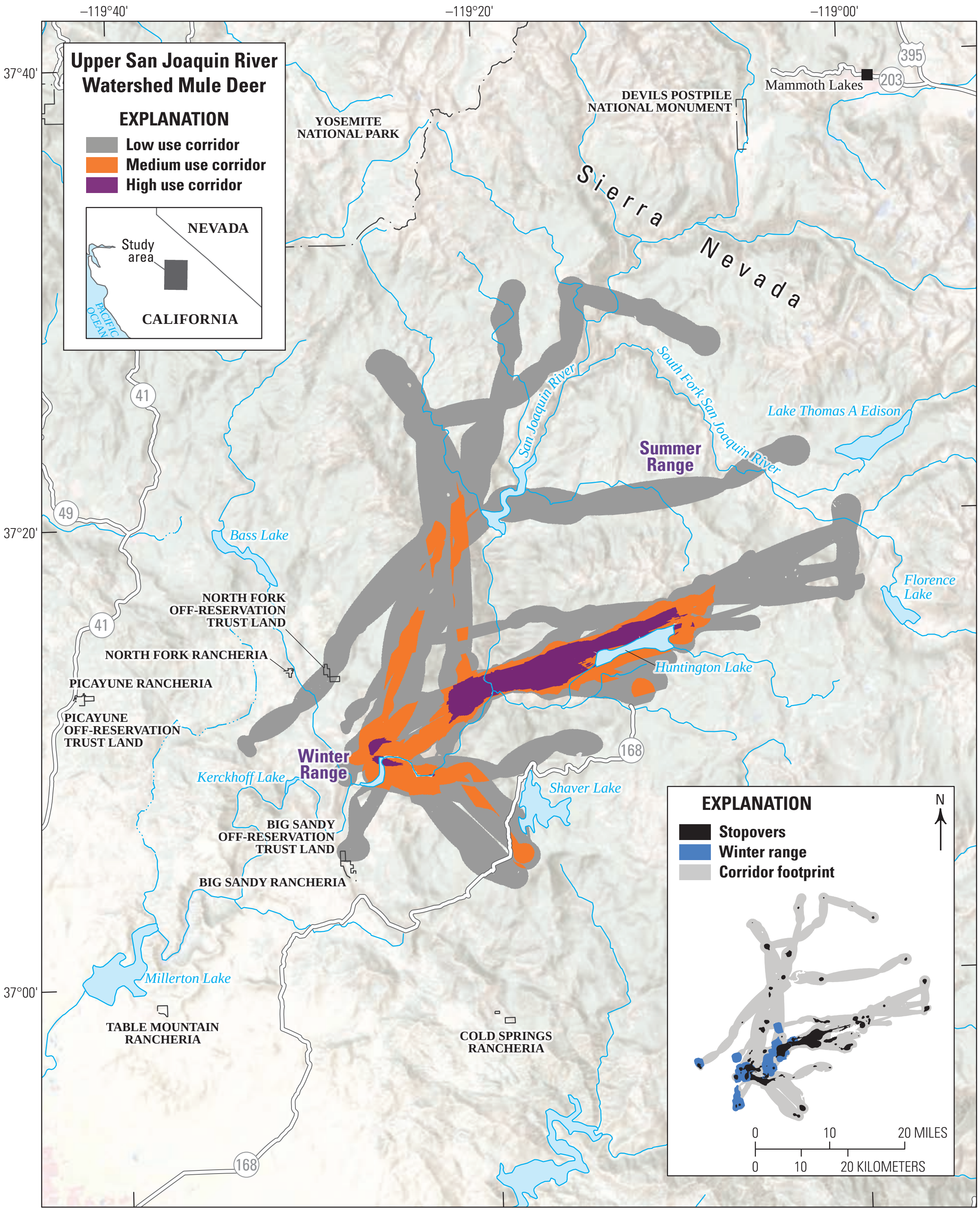
Data analyst:

- Evan Greenspan, Senior GIS Analyst, California Department of Fish and Wildlife

Reports and publications:

- Leopold, A.S., Riney, T., McCain, R., and Tevis, L., Jr., 1951, The Jawbone Deer Herd: California Game Bulletin no. 4. 139 p.

Photograph from Nathan Graveline, California Department of Fish and Wildlife.



Base from ESRI and U.S. Geological Survey digital data, 2019
Universal Transverse Mercator projection, zone 11N
North American Datum of 1983

Figure 13. Migration corridors, stopovers, and winter ranges of the Upper San Joaquin River Watershed mule deer herd.

California | Mule Deer

Upper San Joaquin River Watershed Mule Deer

Migratory mule deer within the Upper San Joaquin River watershed occupy most of the watershed above Kerckhoff Lake, Fresno and Madera Counties, California (fig. 13). Human infrastructure in the watershed is widespread and includes residential, water control, hydroelectric power, and recreational use developments. Steep topography between winter and summer range limit crossing points along the San Joaquin River. Habitat conditions favoring mule deer declined from a peak around 1950, resulting in a reduction in the mule deer population. The mule deer population is approximately 4,000. A massive wildfire burned most of the watershed in 2020, dramatically changing habitat conditions in some areas.

Animal Capture and Data Collection

Sample size: 48 adult or juvenile female mule deer, 1 juvenile male mule deer

Relocation frequency: 2–12 hours

Project duration: 2013–2016

Data Analysis

Corridor, stopover, and winter range analysis: Brownian bridge movement models (Sawyer and others, 2009); corridor analysis used Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 55 sequences from 30 individuals (33 spring sequences, 22 fall sequences)
- Winter: 44 sequences from 32 individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: April 19 to April 28
- Fall: November 1 to November 3

Average number of days migrating:

- Spring: 8 days
- Fall: 10 days

Migration corridor length:

- Minimum: 0.08 mi (0.13 km)
- Mean: 13.37 mi (21.52 km)
- Maximum: 26.62 mi (42.84 km)

Migration corridor area:

- 16,2295 acres (65,679 ha) (low use)
- 35,385 acres (14,320 ha) (medium use)
- 10,032 acres (4,060 ha) (high use)
- Stopover area: 16,729 acres (6,770 ha)

Winter Range Summary

Winter start and end dates (median):

- November 3 to April 20
- Winter use length (mean): 188 days
- Winter range (50 percent contour) area: 15,518 acres (6,280 ha)

Other Information

Project contacts:

- Julie Garcia (Julie.garcia@wildlife.ca.gov), Deer Biologist, California Department of Fish and Wildlife
- Tim Kroeker (tim.kroeker@wildlife.ca.gov), Environmental Scientist, California Department of Fish and Wildlife Central Region

Data analyst:

- Evan Greenspan, Senior GIS Analyst, California Department of Fish and Wildlife

Reports and publications:

- Kroeker, T.G., 2018. Upper San Joaquin watershed deer herd delineation, migratory behavior, and population dynamic telemetry project final report, Fresno, Calif., California Department of Fish and Wildlife, p. 1–42. [Also available at https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=156524.]

Photograph from Tim Kroeker, California Department of Fish and Wildlife.

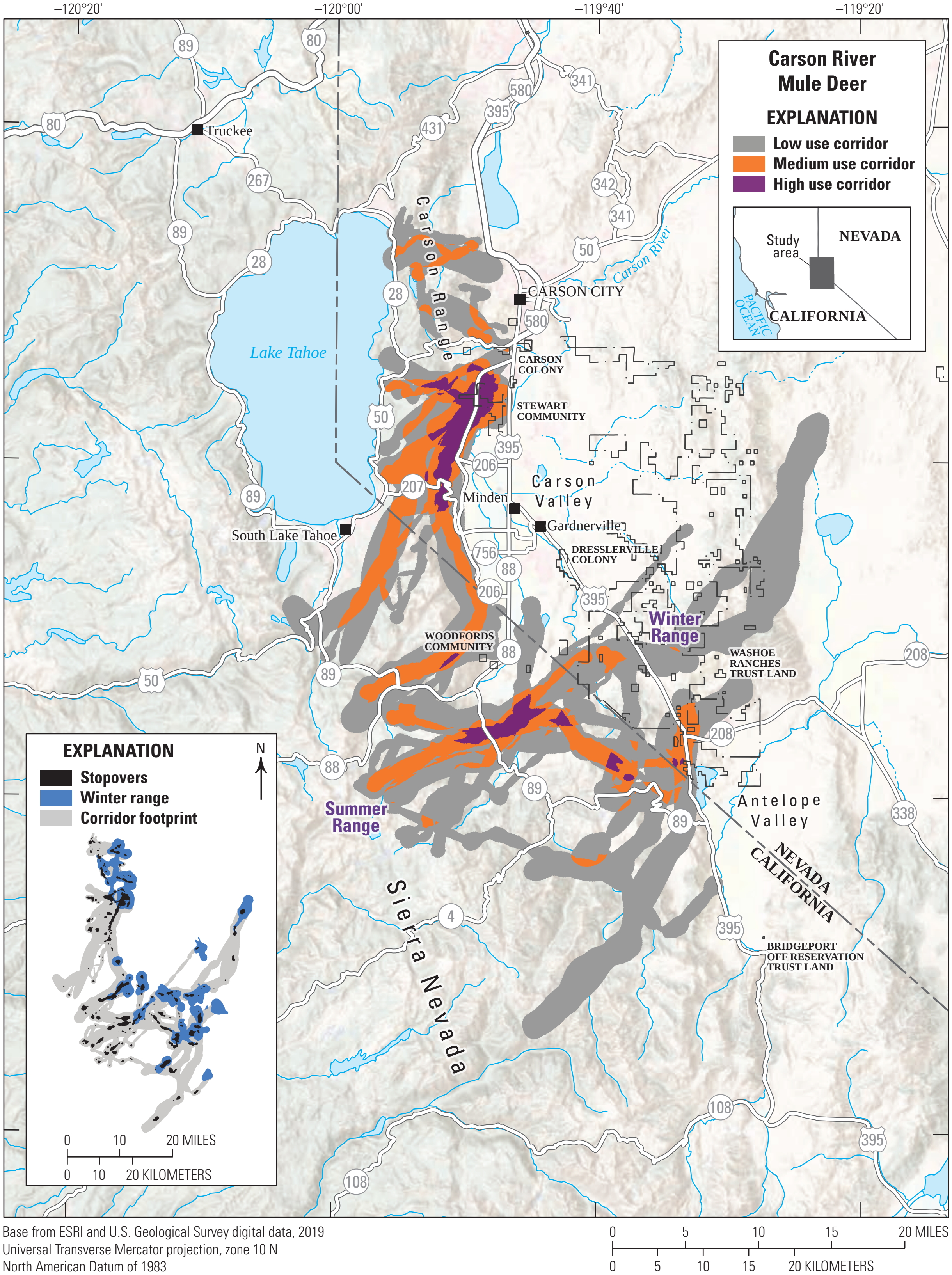


Figure 14. Migration corridors, stopovers, and winter ranges of the Carson River mule deer herd.

California and Nevada | Mule Deer

Carson River Mule Deer

A significant portion of the Carson River mule deer herd summers in the Sierra Nevada of California and migrates to a winter range near the California–Nevada border (fig. 14). Herd size has declined significantly (greater than 70 percent) from historical peak levels, likely because of habitat loss and vehicle collisions. A large increase in housing development and traffic along the U.S. Highway 395 corridor during the past 20 years has contributed to population declines for this herd. Significant barriers include fencing along Carson River and outlying suburban areas in Carson City, Minden, and Gardnerville, Nevada.

Animal Capture and Data Collection

Sample size: 84 adult female mule deer, 3 adult male mule deer

Relocation frequency: 2–12 hours

Project duration: 2012–2019

Data Analysis

Corridor, stopover, and winter range analysis: Brownian bridge movement models (Sawyer and others, 2009); corridor analysis used Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 110 sequences from 45 individuals (61 spring sequences, 49 fall sequences)
- Winter: 92 sequences from 48 individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: May 1 to May 9
- Fall: November 1 to November 7

Average number of days migrating:

- Spring: 10 days
- Fall: 7 days

Migration corridor length:

- Minimum: 2.19 mi (3.52 km)
- Mean: 12.95 mi (20.84 km)
- Maximum: 26.98 mi (43.42 km)

Migration corridor area:

- 332,757 acres (134,662 ha) (low use)
- 85,932 acres (34,775 ha) (medium use)
- 16,037 acres (6,490 ha) (high use)
- Stopover area: 36,372 acres (14,719 ha)

Winter Range Summary

Winter start and end dates (median):

- November 7 to May 3
- Winter use length (mean): 174 days
- Winter range (50 percent contour) area: 108,567 acres (43,936 ha)

Other Information

Project contacts:

- Julie Garcia (Julie.garcia@wildlife.ca.gov), Deer Biologist, California Department of Fish and Wildlife
- Shelly Blair (shelly.blair@wildlife.ca.gov), Environmental Scientist, California Department of Fish and Wildlife
- Cody Schroeder (cschroeder@ndow.org), Wildlife Staff Specialist, Nevada Department of Wildlife
- Carl Lackey (clackey@ndow.org), Game Biologist, Nevada Department of Wildlife

Data analyst:

- Evan Greenspan, Senior GIS Analyst, California Department of Fish and Wildlife

Photograph from Cody Schroeder, Nevada Department of Wildlife.

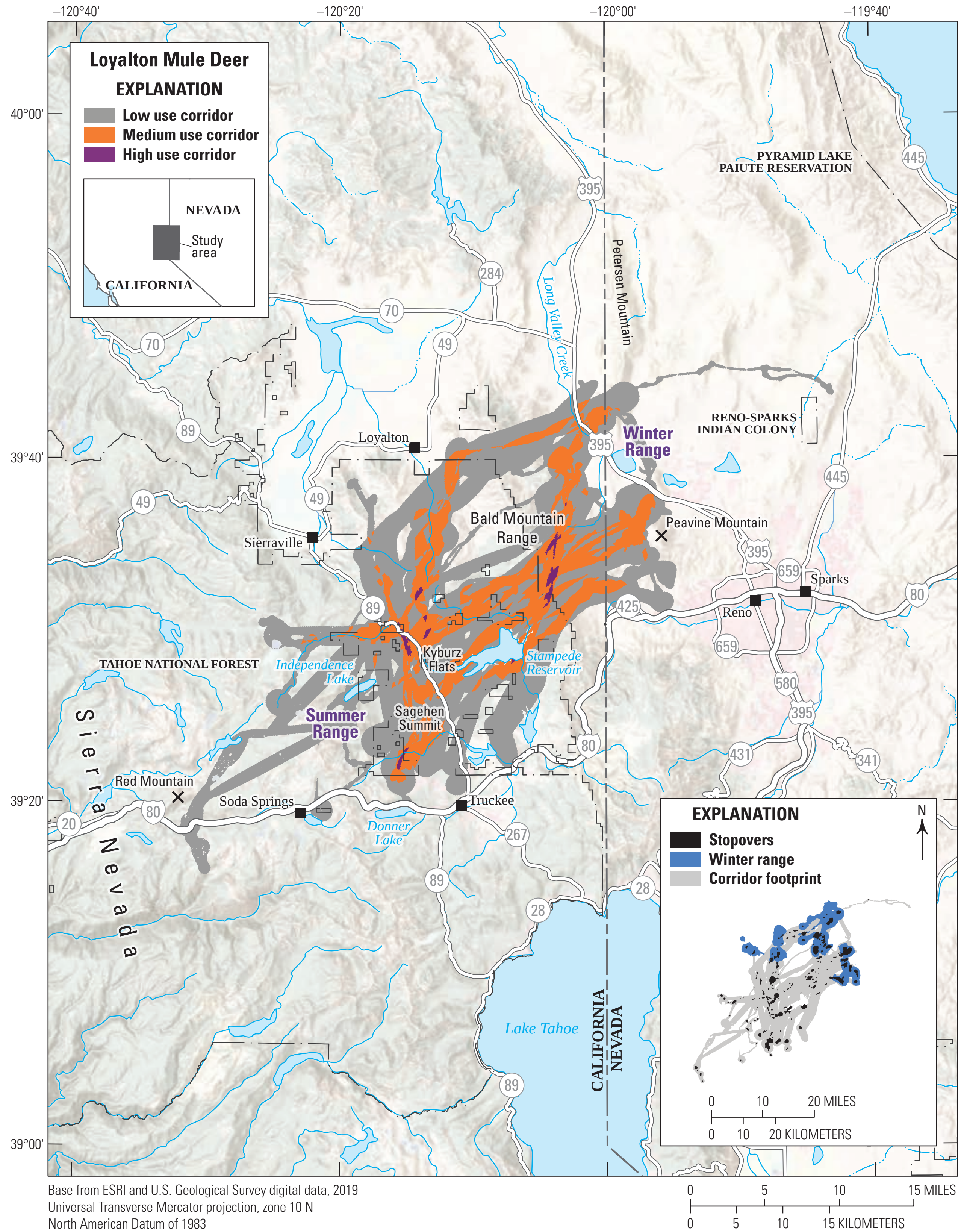


Figure 15. Migration corridors, stopovers, and winter ranges of the Loyalton mule deer herd.

California and Nevada | Mule Deer

Loyalton Mule Deer

The Loyalton mule deer herd winters west and northwest of Reno, Nevada, along the California–Nevada border, extending into the Petersen Mountains, east of U.S. Highway 395 in Nevada (fig. 15). A portion of the herd also winters north of Interstate 80 on Peavine Mountain in Nevada. This population represents an interstate migratory herd but also contains year-round residents in both states. Mule deer migrate southwest into the Sierra Nevada in California on both sides of U.S. Highway 89 from Tru ckee to Sierraville, California, mostly staying north of Interstate 80 and into the Tahoe National Forest. Significant challenges include urban development, vehicle collisions on U.S. Highways 89 and 395 and Interstate 80, and large-scale wildfires burned winter ranges in both states. Three U.S. Highway 89 wildlife crossing structures were installed by California Department of Transportation and the Highway 89 Stewardship Team at Kyburz Flat and two at Sagehen Hills to mitigate effects from vehicle collisions.

Animal Capture and Data Collection

Sample size: 36 mule deer
Relocation frequency: 1–3 hours
Project duration: 2006–2017

Data Analysis

Corridor, stopover, and winter range analysis: Brownian bridge movement models (Sawyer and others, 2009); corridor analysis used Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 76 sequences from 31 individuals (38 spring sequences, 38 fall sequences)
- Winter: 62 sequences from 31 individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: May 5 to May 12
- Fall: October 24 to November 1

Average number of days migrating:

- Spring: 10 days
- Fall: 10 days

Migration corridor length:

- Minimum: 8.64 mi (13.91 km)
- Mean: 34.30 mi (55.20 km)
- Maximum: 216.36 mi (348.20 km)

Migration corridor area:

- 226,488 acres (91,656 ha) (low use)
- 59,518 acres (24,086 ha) (medium use)
- 1,911 acres (773 ha) (high use)
- Stopover area: 23,697 acres (9,590 ha)

Winter Range Summary

Winter start and end dates (median):

- November 2 to May 4
- Winter use length (mean): 183 days
- Winter range (50 percent contour) area: 58,756 acres (23,778 ha)

Other Information

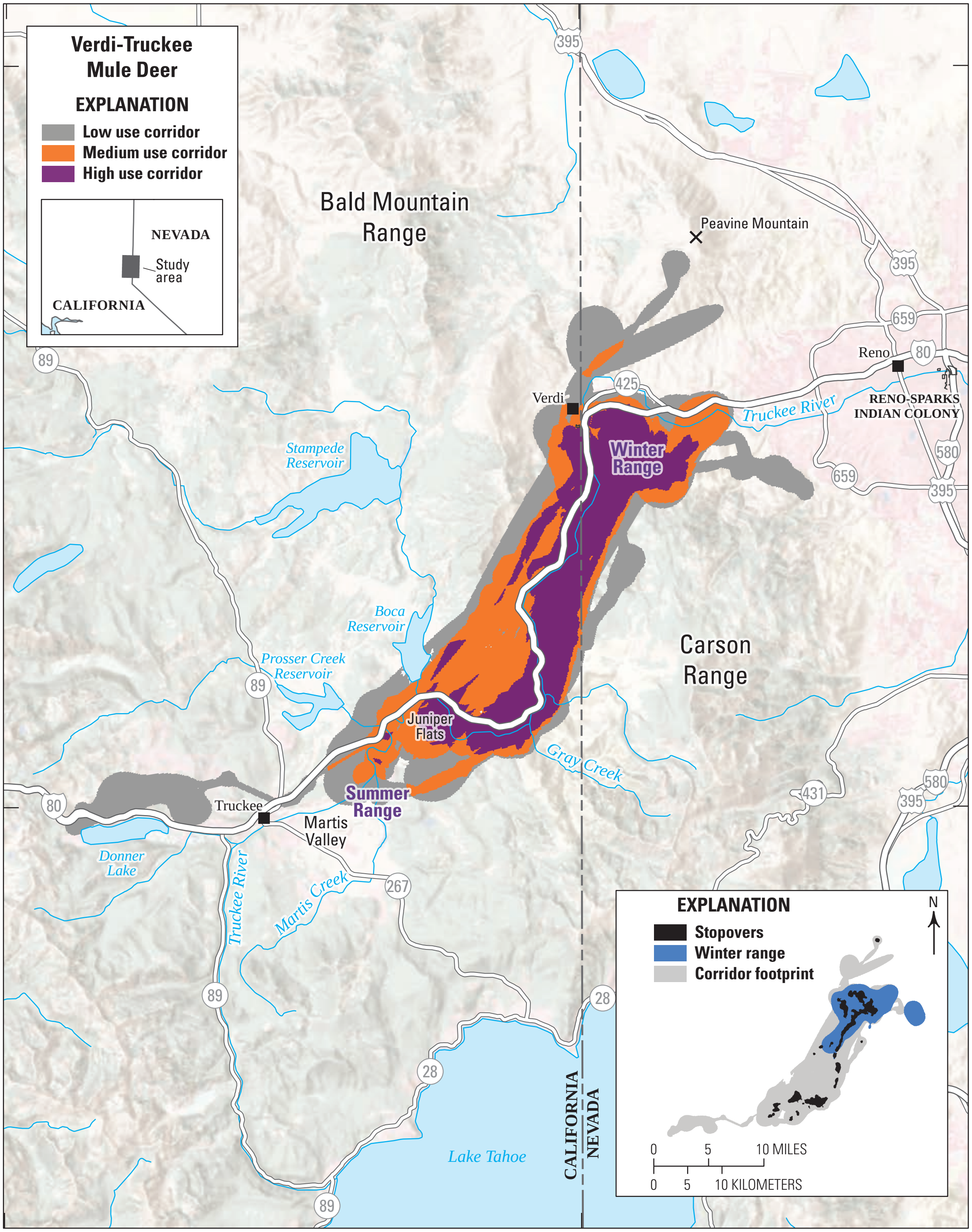
Project contacts:

- Julie Garcia (Julie.garcia@wildlife.ca.gov), Deer Biologist, California Department of Fish and Wildlife
- Sara Holm (Sara.holm@wildlife.ca.gov), Wildlife Biologist, California Department of Fish and Wildlife.
- Cody Schroeder (cschroeder@ndow.org), Wildlife Staff Specialist, Nevada Department of Wildlife
- Carl Lackey (clackey@ndow.org), Game Biologist, Nevada Department of Wildlife

Data analyst:

- Cody Schroeder, Wildlife Staff Specialist, Nevada Department of Wildlife

Photograph from Mark Enders, Nevada Department of Wildlife.



Base from ESRI and U.S. Geological Survey digital data, 2019
Universal Transverse Mercator projection, zone 10 N
North American Datum of 1983

0 2 4 6 8 MILES
0 2 4 6 8 KILOMETERS

Figure 16. Migration corridors, stopovers, and winter ranges of the Verdi-Truckee mule deer herd.

California and Nevada | Mule Deer

Verdi-Truckee Mule Deer

The Verdi-Truckee mule deer herd winters south of Interstate 80 in the Carson Range along the California–Nevada border, although a portion of this herd winters northeast of Verdi, Nevada on Peavine Mountain (fig. 16). Migration routes to summer range follow Interstate 80 southwest, along both sides of the Truckee River, toward Martis Valley and Truckee, California. The summer range for this small herd (approximately 500 animals in 2019) is located east of Truckee and includes portions of Juniper Flat, Martis Creek, and the area south of the Truckee River to the confluence of Gray Creek. Migration behavior and timing of migration is dependent on seasonal weather conditions and snow depth during early winter. Significant challenges to this mule deer herd include barriers to movement, such as Interstate 80, vehicle collisions, and increased housing development on winter range in Verdi neighborhoods.

Animal Capture and Data Collection

Sample size: 35 adult female mule deer
Relocation frequency: 1–11 hours
Project duration: 2009–2017

Data Analysis

Corridor, stopover, and winter range analysis: Brownian bridge movement models (Sawyer and others, 2009); corridor analysis used Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 91 sequences from 31 individuals (39 spring sequences, 52 fall sequences)
- Winter: 74 sequences from 31 individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: May 3 to May 6
- Fall: November 23 to November 27

Average number of days migrating:

- Spring: 6 days
- Fall: 7 days

Migration corridor length:

- Minimum: 4.60 mi (7.40 km)
- Mean: 14.90 mi (23.98 km)
- Maximum: 44.36 mi (71.39 km)

Migration corridor area

- 51,773 acres (20,952 ha) (low use)
- 30,678 acres (12,415 ha) (medium use)
- 16,246 acres (6,575 ha) (high use)
- Stopover area: 5,603 acres (2,268 ha)

Winter Range Summary

Winter start and end dates (median):

- November 29 to May 6
- Winter use length (mean): 207 days
- Winter range (50 percent contour) area: 16,240 acres (6,572 ha)

Other Information

Project contacts:

- Julie Garcia (Julie.garcia@wildlife.ca.gov), Deer Biologist, California Department of Fish and Wildlife
- Sara Holm (sara.holm@wildlife.ca.gov), Wildlife Biologist, California Department of Fish and Wildlife
- Cody Schroeder (cschroeder@ndow.org), Wildlife Staff Specialist, Nevada Department of Wildlife
- Carl Lackey (clackey@ndow.org), Game Biologist, Nevada Department of Wildlife

Data analyst:

- Cody Schroeder, Wildlife Staff Specialist, Nevada Department of Wildlife

Photograph from Cody Schroeder, Nevada Department of Wildlife.

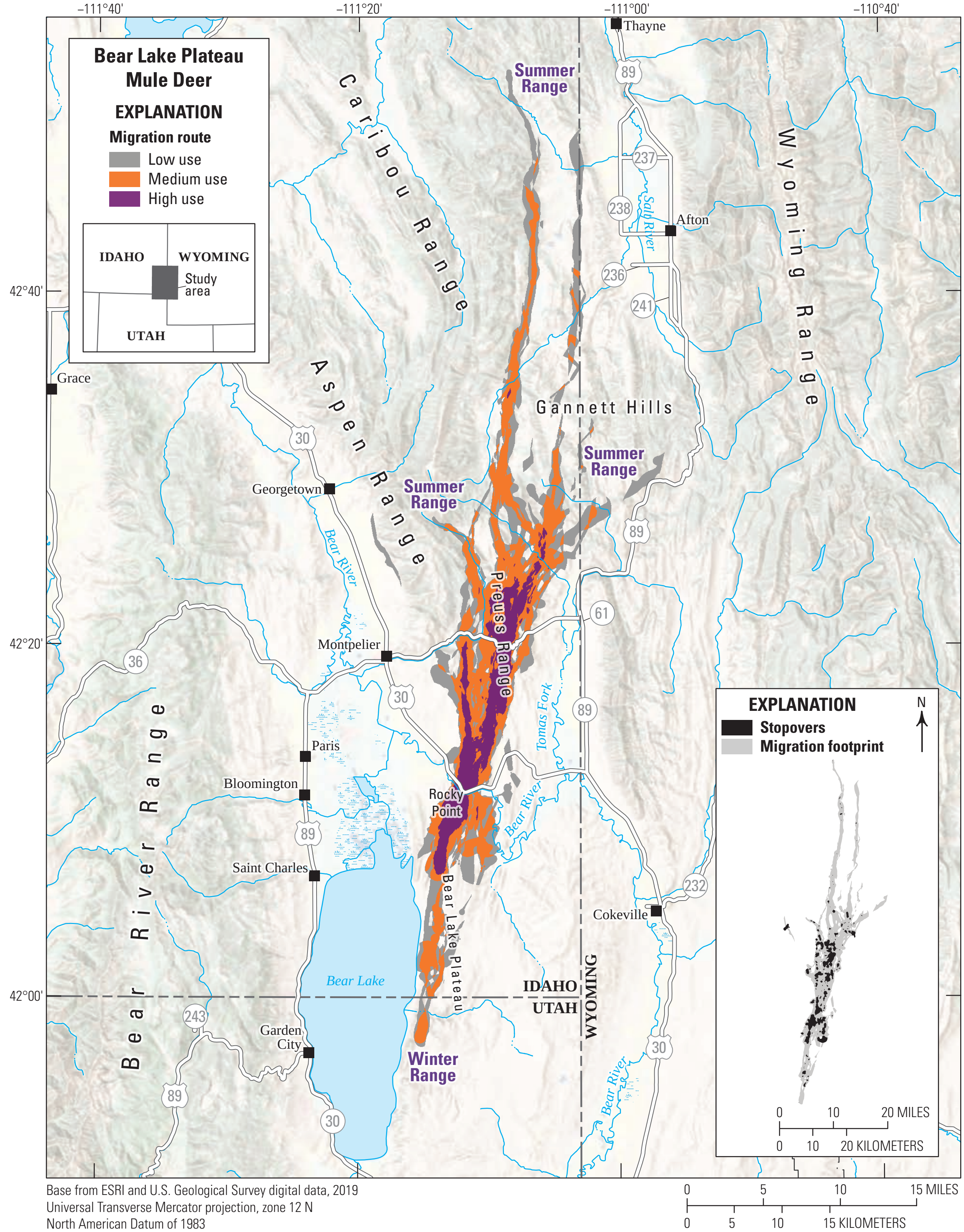


Figure 17. Migration routes and stopovers of the Bear Lake Plateau mule deer herd.

Idaho | Mule Deer

Bear Lake Plateau Mule Deer

The winter range for the tristate Bear Lake Plateau mule deer herd is on the Bear Lake Plateau in Idaho and Utah (fig. 17). The seasonal migration route for this mule deer herd is funneled through the Rocky Point section where state highways, the Bear River, and railways converge and the migration route is condensed. Once crossing these natural and manmade barriers, the migration follows the Preuss Range north into summer ranges splitting off from the predominant migration route. These summer ranges include the Gannett Hills in Wyoming, and the Aspen and Caribou Ranges in Idaho. Challenges to this herd include vehicular collision, wildlife unfriendly fencing, and mining developments in their summer range.

Animal Capture and Data Collection

Sample size: 28 adult female mule deer
Relocation frequency: 2 hours
Project duration: 2018–present

Data Analysis

Migration and stopover analysis: Brownian bridge movement models (Sawyer and others, 2009)

Models derived from:

- Migration: 52 sequences from 28 individuals (28 spring sequences, 24 fall sequences)

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: April 13 to May 15
- Fall: October 28 to November 19

Average number of days migrating:

- Spring: 32.4 days
- Fall: 22.0 days

Migration length:

- Minimum: 5.0 mi
- Mean: 37.2 mi
- Maximum: 70.9 mi

Migration area:

- 105,167 acres (low use)
- 60,810 acres (medium use)
- 18,233 acres (high use)
- Stopover area: 19,798 acres

Other Information

Project contacts:

- Matt Pieron (matt.pieron@idfg.idaho.gov) Mule Deer Initiative Coordinator, Idaho Department of Fish and Game
- Zach Lockyer (zach.lockyer@idfg.idaho.gov) Regional Wildlife Manager, Idaho Department of Fish and Game
- Eric Freeman (eric.freeman@idfg.idaho.gov) Regional Wildlife Biologist, Idaho Department of Fish and Game

Data analysts:

- Jodi Berg, Senior Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming
- Scott Bergen, Senior Wildlife Research Biologist, Idaho Department of Fish and Game

Reports and publications:

- Ellstrom, M., Hickey, C., Ward, R., Berkley, R., McDonald, M., Lockyer, Z., Hendricks, C., Painter, G., Roche, E., Elmer, M., and Smith, D., 2019, Mule deer surveys and inventories statewide report 2018 seasons: Boise, Idaho, Idaho Department of Fish and Game, 117 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/Mule%20Deer%20Statewide%20FY2019.pdf.]
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game, 49 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/ID%20F16AF00908%20Statewide%20Wildlife%20Research%20Report%20FY18.pdf.]

Photograph from Idaho Department of Fish and Game.

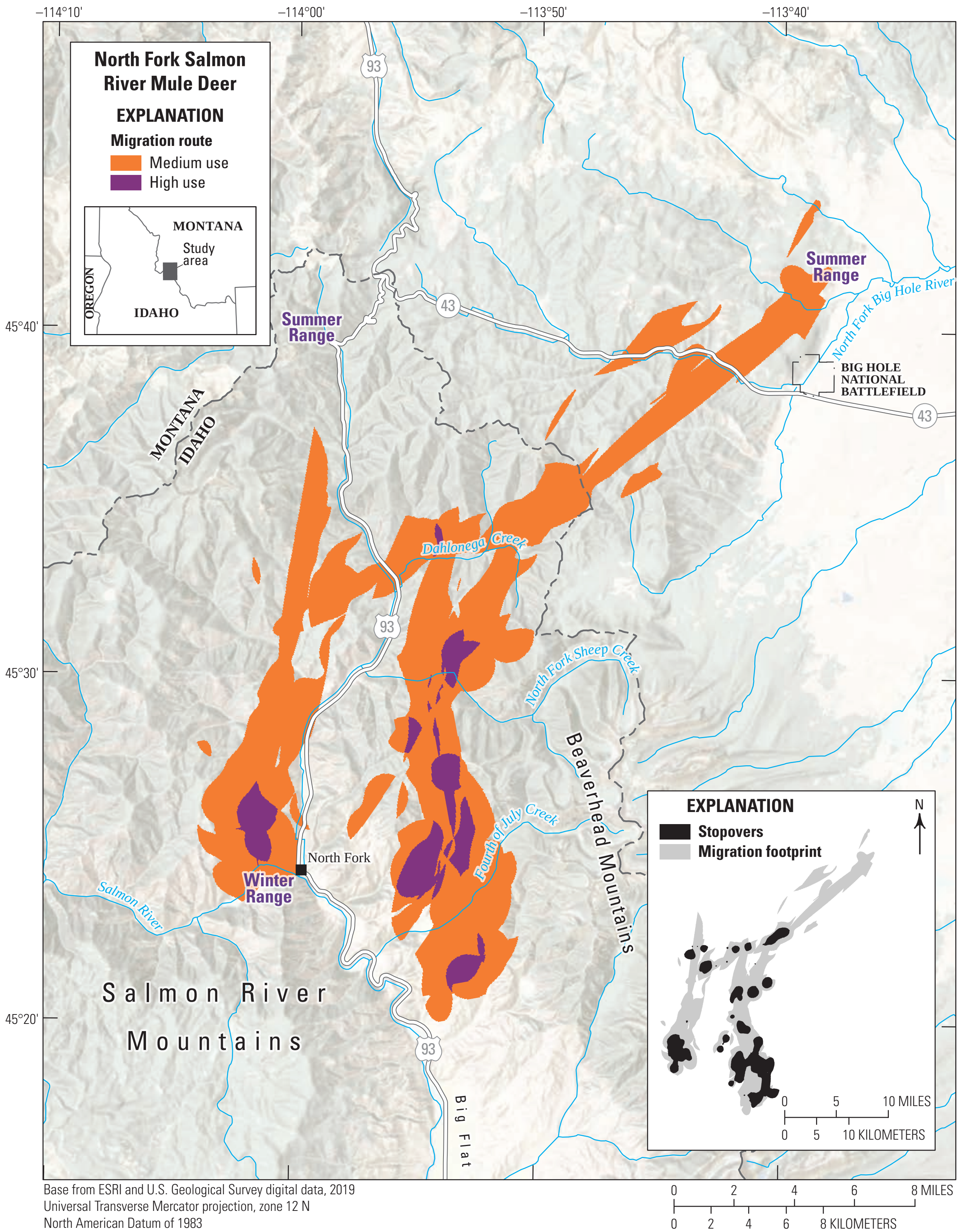


Figure 18. Migration routes and stopovers of the North Fork Salmon River mule deer herd.

Idaho | Mule Deer

North Fork Salmon River Mule Deer

North Fork Salmon River mule deer winter in the foothills of the Beaverhead Mountains and along the Salmon River valley near North Fork, Idaho (fig. 18). They generally travel northeast across the Beaverhead Mountains towards summer ranges in Montana. On average, North Fork Salmon River mule deer travel 33 miles to migrate between summer and winter ranges, with more extensive migrations reaching 65 miles. Winter range is characterized by open sagebrush-grassland foothills, with summer range more forested and more productive because of increased precipitation. Snow depth during the spring migration can be significant when crossing the mountains. The wintering population of mule deer used for this analysis approximated 3,000 in 2016.

Animal Capture and Data Collection

Sample size: 16 female mule deer
Relocation frequency: 2–13 hours
Project duration: May 2013–October 2018

Data Analysis

Migration and stopover analysis: Brownian bridge movement models (Sawyer and others, 2009); Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 31 sequences from 16 individuals (20 spring sequences, 11 fall sequences)

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: April 28 to May 24
- Fall: September 26 to October 29

Average number of days migrating:

- Spring: 19 days
- Fall: 33 days

Migration length:

- Minimum: 9.0 mi (14.5 km)
- Mean: 33.4 mi (53.8 km)
- Maximum: 64.5 mi (103.8 km)

Migration area:

- 70,331 acres (28,462 ha) (medium use; 10–20 percent)
- 5,869 acres (2,375 ha) (high use; greater than 20 percent)
- Stopover area: 18,658 acres (7,551 ha)

Other Information

Project contacts:

- Mark Hurley (mark.hurley@idfg.idaho.gov), Wildlife Research Supervisor, Idaho Department of Fish and Game
- Dennis Newman (dennis.newman@idfg.idaho.gov), Regional Wildlife Manager, Idaho Department of Fish and Game

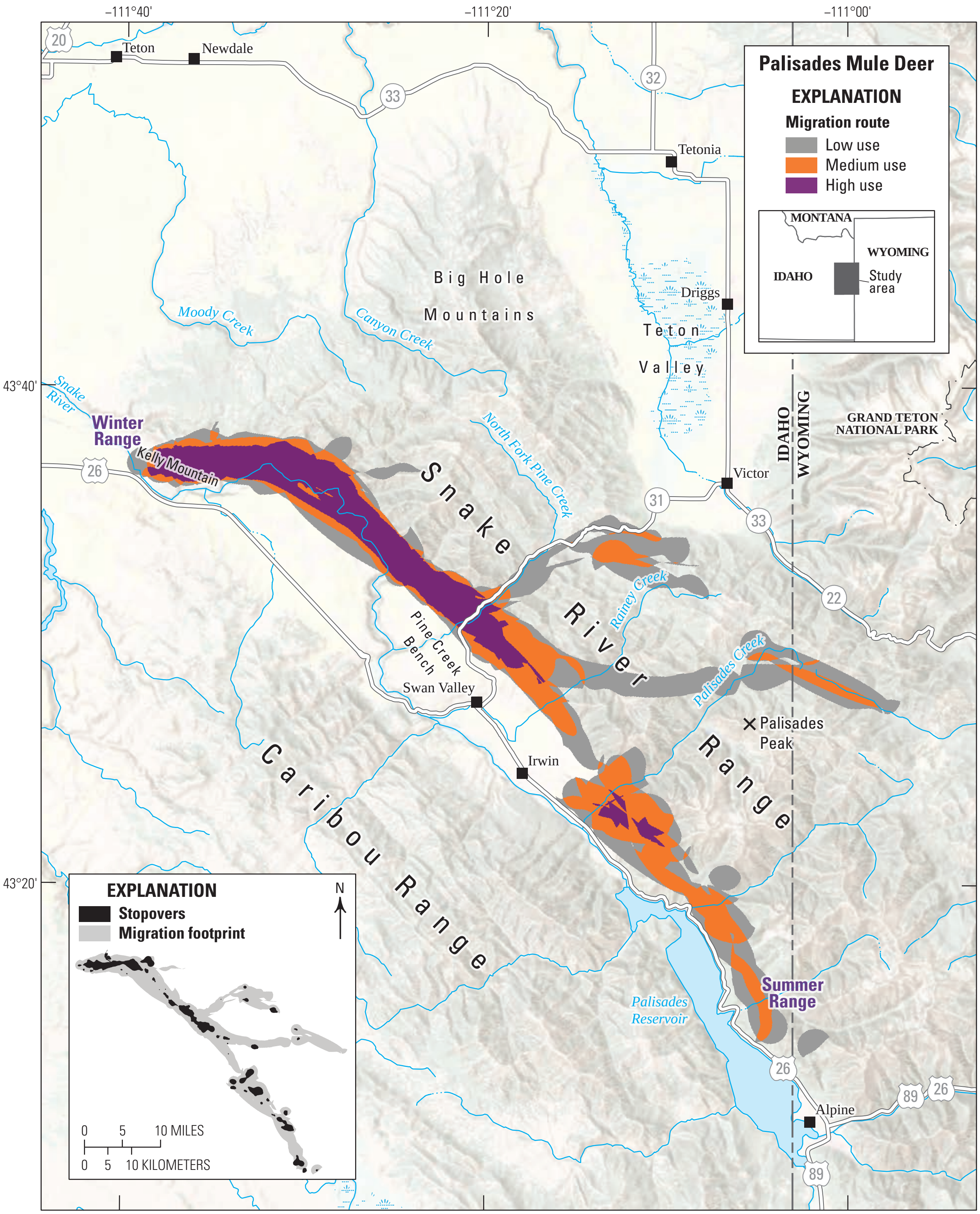
Data analysts:

- Jodi Berg, Senior Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming
- Scott Bergen, Senior Wildlife Research Biologist, Idaho Department of Fish and Game

Reports and publications:

- Ellstrom, M., Hickey, C., Ward, R., Berkley, R., McDonald, M., Lockyer, Z., Hendricks, C., Painter, G., Roche, E., Elmer, M., and Smith, D., 2019, Mule deer surveys and inventories statewide report 2018 seasons: Boise, Idaho, Idaho Department of Fish and Game, 117 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/Mule%20Deer%20Statewide%20FY2019.pdf.]
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game, 49 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/ID%20F16AF00908%20Statewide%20Wildlife%20Research%20Report%20FY18.pdf.]

Photograph from James Brower, Idaho Department of Fish and Game.



Base from ESRI and U.S. Geological Survey digital data, 2019
Universal Transverse Mercator projection, zone 12 N
North American Datum of 1983

Figure 19. Migration routes and stopovers of the Palisades mule deer herd.

Idaho | Mule Deer

Palisades Mule Deer

The Palisades mule deer herd winter in GMU 67, north of the Snake River in the Big Hole Mountains in Idaho, with the largest concentrations wintering on sagebrush steppe and juniper slopes near Kelly Mountain, in the Snake River valley, and along Pine Creek Bench (fig. 19). Much of the winter range is associated with the southern aspects along the Snake River. The river and associated topography are a funnel for many of these mule deer, as they follow the river southeast towards summer ranges in the Palisades and Snake River Ranges north and east of U.S. Highway 26 and the Palisades Reservoir. Other mule deer make shorter movements to the north, spending time along the boundaries of GMU 64 and 65. Some mule deer summer in Wyoming. On average, Palisades mule deer travel 28 miles to migrate between summer and winter ranges, with more extensive migrations measuring more than 53 miles. Migration routes of this population cross and run adjacent to State Highway 31 and U.S. Highway 26, where wildlife-vehicle collisions occur frequently. The Palisades population is the largest component (approximately 80 percent) of the mule deer in the Big Hole Mountains and the portion of the Snake River Range in Idaho. The total population ranges between 3,500 and 5,000 mule deer; in January 2021, the winter population of mule deer used in this analysis approximated 2,300 for the Heise and Swan Valley concentration, 400 mule deer for the Teton Basin area, and 800 mule deer for the Canyon Creek and Moody Creek areas. It is important to note that the results of the January 2021 population survey and subsequent estimates show significant mortality related to winter severity. The 2021 population estimate is likely about only 50 percent of what the population was in fall 2016. The Palisades mule deer population has access to an abundant, high-quality summer range, but is limited by periodic severe winters when conditions push them to terminal winter range. These terminal ranges are a mix of public and private lands that are changing rapidly. The development and conversion of these ranges from shrubs to grass for livestock grazing will reduce their carrying capacity and likely will result in reduced populations of mule deer. Thus, protection of the winter ranges and functional migration routes may need to be considered for prioritization.

Animal Capture and Data Collection

Sample size: 21 female mule deer
Relocation frequency: 2–13 hours
Project duration: April 2013–December 2018

Data Analysis

Migration and stopover analysis: Brownian bridge movement models (Sawyer and others, 2009); Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 28 sequences from 21 individuals (17 spring sequences, 11 fall sequences)

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: April 30 to May 30
- Fall: November 9 to December 6

Average number of days migrating:

- Spring: 16 days
- Fall: 14 days

Migration length:

- Minimum: 6.2 mi (10.0 km)
- Mean: 28.0 mi (45.1 km)
- Maximum: 53.7 mi (92.2 km)

Migration area:

- 156,216 acres (251,405 ha) (low use; 10 percent)
- 69,493 acres (111,838 ha) (medium use; 10–20 percent)
- 21,869 acres (35,195 ha) (high use; greater than 20 percent)
- Stopover area: 16,070 acres (25,862 ha)

Other Information

Project contacts:

- Mark Hurley (mark.hurley@idfg.idaho.gov), Wildlife Research Supervisor, Idaho Department of Fish and Game
- Curtis Hendricks (curtis.hendricks@idfg.idaho.gov), Regional Wildlife Manager, Idaho Department of Fish and Game

Data analysts:

- Jodi Berg, Senior Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming
- Scott Bergen, Senior Wildlife Research Biologist, Idaho Department of Fish and Game

Reports and publications:

- Ellstrom, M., Hickey, C., Ward, R., Berkley, R., McDonald, M., Lockyer, Z., Hendricks, C., Painter, G., Roche, E., Elmer, M., and Smith, D., 2019, Mule deer surveys and inventories statewide report 2018 seasons: Boise, Idaho, Idaho Department of Fish and Game, 117 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/Mule%20Deer%20Statewide%20FY2019.pdf.]
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game, 49 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/ID%20F16AF00908%20Statewide%20Wildlife%20Research%20Report%20FY18.pdf.]

Photograph from Idaho Department of Fish and Game.

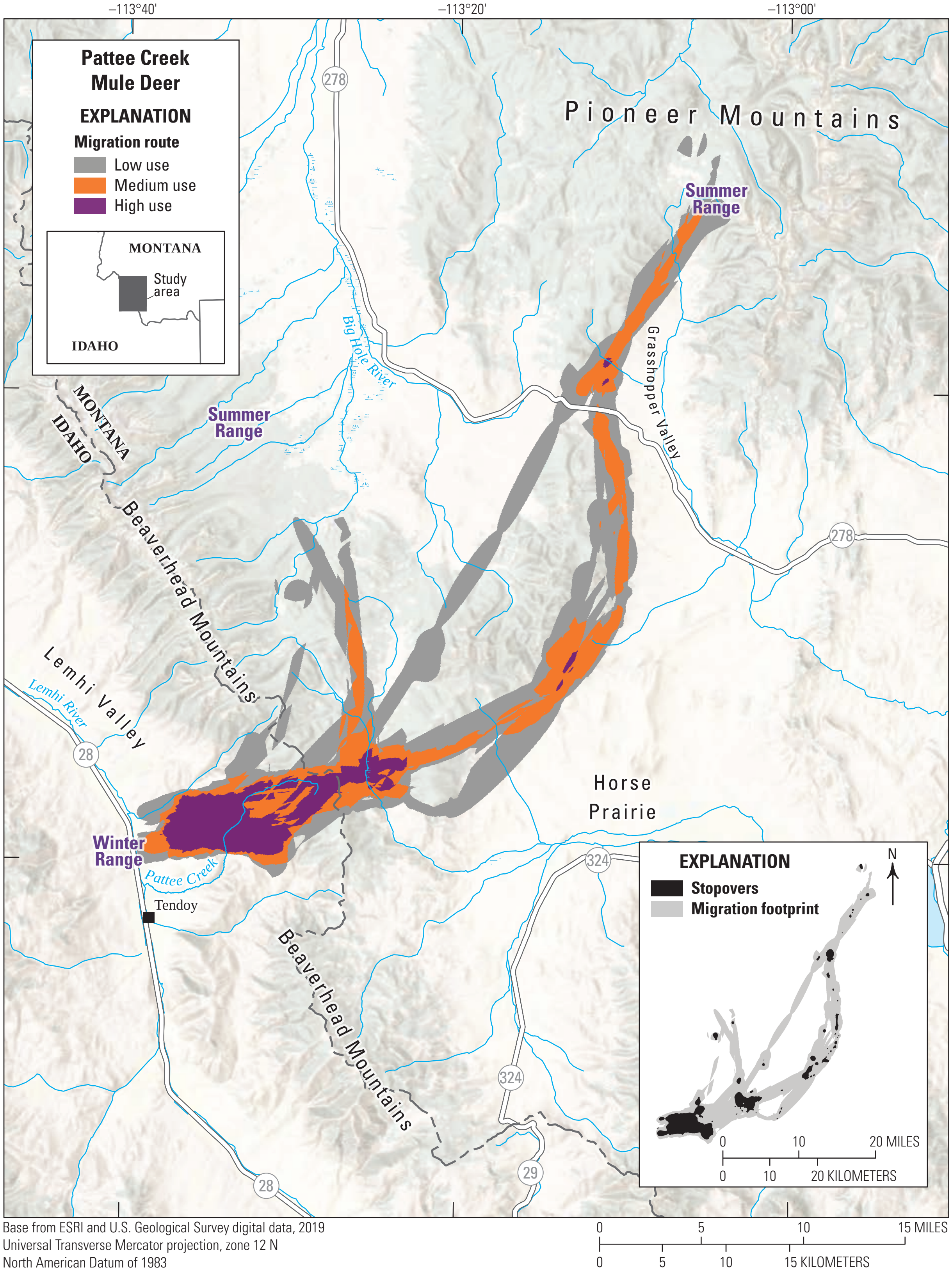


Figure 20. Migration routes and stopovers of the Pattee Creek mule deer herd.

Idaho | Mule Deer

Pattee Creek Mule Deer

Pattee Creek mule deer winter in the Lemhi Valley north of Tendoy and Pattee Creek in Idaho. These mule deer generally cross the Beaverhead Mountains near the headwaters of Pattee Creek and migrate north of Horse Prairie to summer in the Pioneer Mountains in Montana (fig. 20). On average, Pattee Creek mule deer travel more than 29 miles to migrate between summer and winter ranges, with more extensive migrations measuring 67 miles. The wintering population of mule deer used for this analysis approximated 1,800 observed individuals in 2016. Managing for quality winter range resilient to invasive plants and noxious weeds is a priority in sustaining healthy mule deer populations in this area.

Animal Capture and Data Collection

Sample size: 33 female mule deer
Relocation frequency: 2–13 hours
Project duration: May 2012–October 2018

Data Analysis

Migration and stopover analysis: Brownian bridge movement models (Sawyer and others, 2009); Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 53 sequences from 33 individuals (37 spring sequences, 16 fall sequences)

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: May 3 to May 24
- Fall: October 3 to October 9

Average number of days migrating:

- Spring: 18 days
- Fall: 10 days

Migration length:

- Minimum: 3.4 mi (5.5 km)
- Mean: 29.7 mi (47.8 km)
- Maximum: 67.1 mi (108.0 km)

Migration area:

- 162,340 acres (65,697 ha) (low use; 10 percent)
- 57,913 acres (23,437 ha) (medium use; 10–20 percent)
- 14,655 acres (5,931 ha) (high use; greater than 20 percent)
- Stopover area: 18,600 acres (7,527 ha)

Other Information

Project contacts:

- Mark Hurley (mark.hurley@idfg.idaho.gov), Wildlife Research Supervisor, Idaho Department of Fish and Game
- Dennis Newman (dennis.newman@idfg.idaho.gov), Regional Wildlife Manager, Idaho Department of Fish and Game

Data analyst:

- Jodi Berg, Senior Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming

Reports and publications:

- Ellstrom, M., Hickey, C., Ward, R., Berkley, R., McDonald, M., Lockyer, Z., Hendricks, C., Painter, G., Roche, E., Elmer, M., and Smith, D., 2019, Mule deer surveys and inventories statewide report 2018 seasons: Boise, Idaho, Idaho Department of Fish and Game, 117 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/Mule%20Deer%20Statewide%20FY2019.pdf.]
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game, 49 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/ID%20F16AF00908%20Statewide%20Wildlife%20Research%20Report%20FY18.pdf.]

Photograph from Idaho Department of Fish and Game.

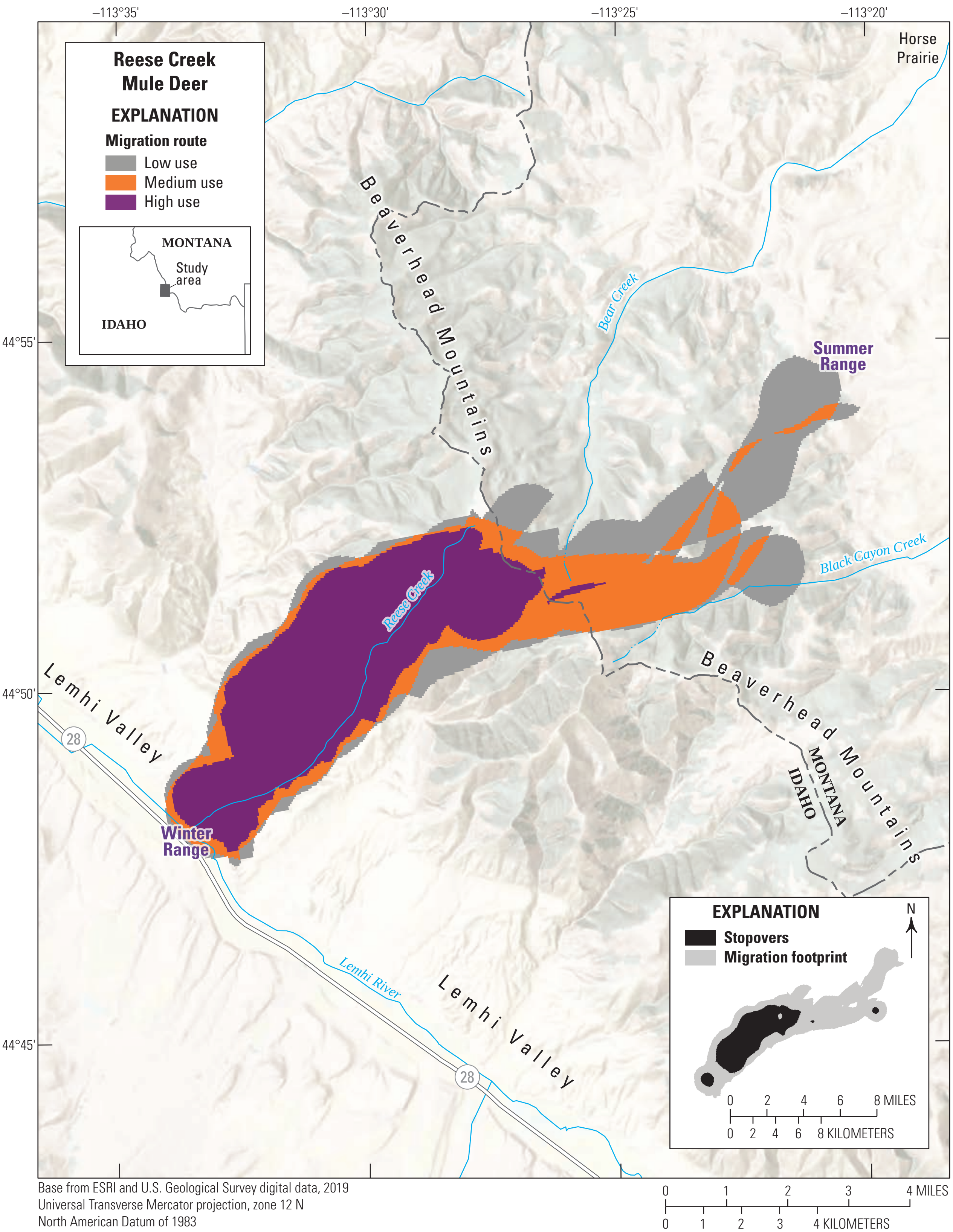


Figure 21. Migration routes and stopovers of the Reese Creek mule deer herd.

Idaho | Mule Deer

Reese Creek Mule Deer

The Reese Creek mule deer herd winters in the Lemhi Valley in Idaho, where Reese Creek meets the Lemhi River (fig. 21). These mule deer generally migrate northeast across the Beaverhead Mountains towards Horse Prairie. On average, Reese Creek mule deer travel more than 16 miles to migrate between summer and winter ranges, with more extensive migrations measuring 56 miles. The wintering population of mule deer used for this analysis approximated 700 observed individuals in 2016. Managing for quality winter range resilient to invasive plants and noxious weeds is a priority in sustaining healthy mule deer populations in this area.

Animal Capture and Data Collection

Sample size: 21 individual mule deer
Relocation frequency: 1–13 hours
Project duration: May 2004–June 2018

Data Analysis

Migration and stopover analysis: Brownian bridge movement models (Sawyer and others, 2009); Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 44 sequences from 21 individuals (30 spring sequences, 14 fall sequences)

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: May 1 to May 29
- Fall: October 31 to December 24

Average number of days migrating:

- Spring: 20 days
- Fall: 46 days

Migration length:

- Minimum: 2.7 mi (4.3 km)
- Mean: 16.7 mi (26.9 km)
- Maximum: 56.3 mi (90.6 km)

Migration area:

- 36,656 acres (14,834 ha) (low use; 10 percent)
- 19,645 acres (7,950 ha) (medium use; 10–20 percent)
- 7,753 acres (3,138 ha) (high use; greater than 20 percent)
- Stopover area: 5,462 acres (2,210 ha)

Other Information

Project contacts:

- Mark Hurley (mark.hurley@idfg.idaho.gov), Wildlife Research Supervisor, Idaho Department of Fish and Game
- Dennis Newman (dennis.newman@idfg.idaho.gov), Regional Wildlife Manager, Idaho Department of Fish and Game

Data analysts:

- Jodi Berg, Senior Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming
- Scott Bergen, Senior Wildlife Research Biologist, Idaho Department of Fish and Game

Reports and publications:

- Ellstrom, M., Hickey, C., Ward, R., Berkley, R., McDonald, M., Lockyer, Z., Hendricks, C., Painter, G., Roche, E., Elmer, M., and Smith, D., 2019, Mule deer surveys and inventories statewide report 2018 seasons: Boise, Idaho, Idaho Department of Fish and Game, 117 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/Mule%20Deer%20Statewide%20FY2019.pdf.]
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game, 49 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/ID%20F16AF00908%20Statewide%20Wildlife%20Research%20Report%20FY18.pdf.]

Photograph from James Brower, Idaho Department of Fish and Game.

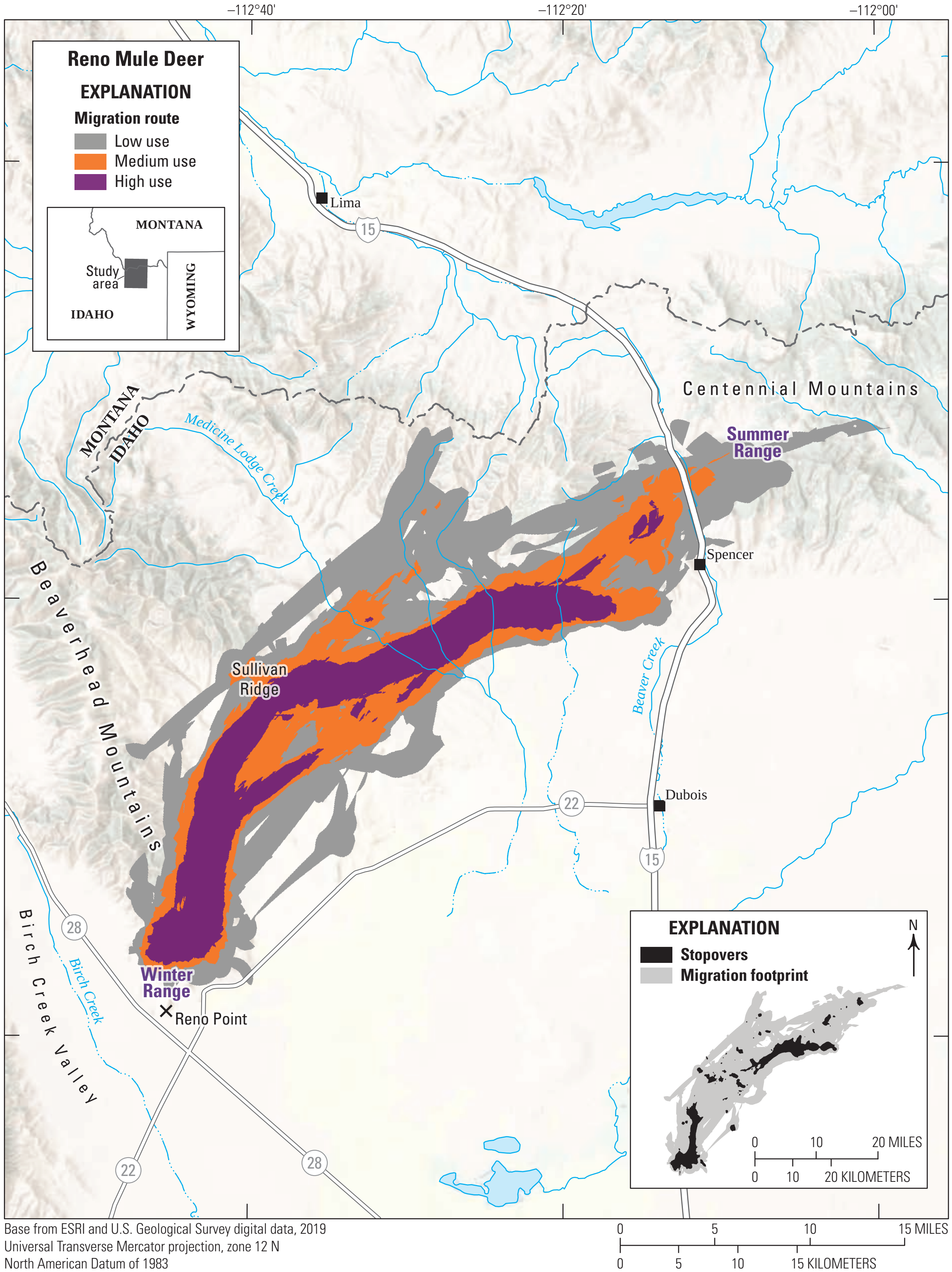


Figure 22. Migration routes and stopovers of the Reno mule deer herd.

Idaho | Mule Deer

Reno Mule Deer

The Reno mule deer herd winters at the southern end of the Beaverhead Mountains in Idaho, congregating at the southern intersection of GMUs 58 and 59A on Reno Point in GMU 59A and in Medicine Lodge Creek drainage at the intersection of GMUs 59A and 59 (fig. 22). Mule deer in this population migrate northeast to reach summer ranges in the Beaverhead Mountains, with some individuals crossing Interstate 15 to summer ranges in the Centennial Mountains. On average, Reno mule deer migrate 36 miles and may migrate as far as 78 miles. This population fluctuates with approximately 3,000 estimated in 2019. The summer and winter ranges of the Reno mule deer are relatively arid, and habitat for these mule deer primarily consists of sagebrush overstory with grass and forb understory at low elevations, particularly on south-facing slopes. Zones of mountain mahogany and juniper become intermixed with sagebrush habitat as elevation increases. Douglas fir communities are common at midelevation zones and on north-facing slopes. Riparian habitats are found adjacent to drainage corridors, which may be ephemeral, and are composed of willow and aspen communities. The highest elevation segments of this region are above tree line and are dominated by alpine and subalpine species. The population is likely limited by summer precipitation and subsequent forage availability, while winter range conditions are relatively mild when compared to the winter ranges of adjacent mule deer populations. Invasive weeds and conversion of shrub-dominated range to grass-dominated range or agriculture are potential risks for this population. Conflict between mule deer and humans has also arisen during both the crop growing season and during crop storage. Especially of note is the expansion of motorized vehicle use, which may place added stress on animals and is a continuing concern for managers.

Animal Capture and Data Collection

Sample size: 56 individual mule deer
Relocation frequency: 2–13 hours
Project duration: April 2009–December 2018

Data Analysis

Migration and stopover analysis: Brownian bridge movement models (Sawyer and others, 2009); Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 140 sequences from 56 individuals (87 spring sequences, 53 fall sequences)

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: April 16 to May 6
- Fall: October 14 to October 21

Average number of days migrating:

- Spring: 20 days
- Fall: 46 days

Migration length:

- Minimum: 9.3 mi (15.0 km)
- Mean: 36.1 mi (58.1 km)
- Maximum: 78.1 mi (125.7 km)

Migration area:

- 368,406 acres (149,089 ha) (low use; 10 percent)
- 153,235 acres (62,012 ha) (medium use; 10–20 percent)
- 51,995 acres (21,042 ha) (high use; greater than 20 percent)
- Stopover area: 34,032 acres (13,772 ha)

Other Information

Project contacts:

- Mark Hurley (mark.hurley@idfg.idaho.gov), Wildlife Research Supervisor, Idaho Department of Fish and Game
- Curtis Hendricks (curtis.hendricks@idfg.idaho.gov), Regional Wildlife Manager, Idaho Department of Fish and Game

Data analysts:

- Jodi Berg, Senior Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming
- Scott Bergen, Senior Wildlife Research Biologist, Idaho Department of Fish and Game

Reports and publications:

- Ellstrom, M., Hickey, C., Ward, R., Berkley, R., McDonald, M., Lockyer, Z., Hendricks, C., Painter, G., Roche, E., Elmer, M., and Smith, D., 2019, Mule deer surveys and inventories statewide report 2018 seasons: Boise, Idaho, Idaho Department of Fish and Game, 117 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/Mule%20Deer%20Statewide%20FY2019.pdf.]
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game, 49 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/ID%20F16AF00908%20Statewide%20Wildlife%20Research%20Report%20FY18.pdf.]

Photograph from Brett Panting, Idaho Department of Fish and Game.

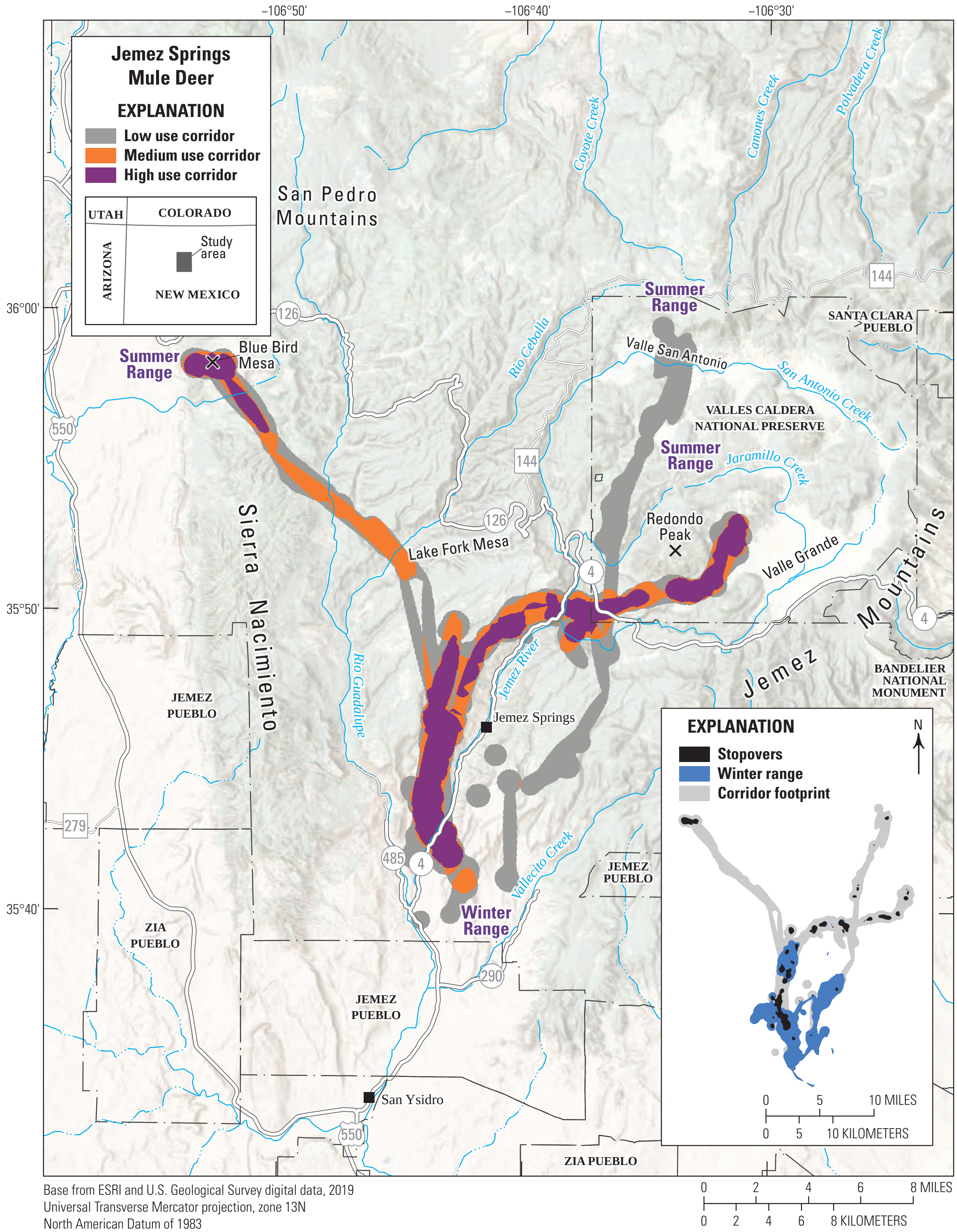


Figure 23. Migration corridors, stopovers, and winter ranges of the Jemez Springs mule deer herd.

New Mexico | Mule Deer

Jemez Springs Mule Deer

The Jemez Springs mule deer herd winters in the southwestern Jemez Mountains, south and east of Jemez Springs, New Mexico (fig. 23). Since the early 2000s, 180,555 acres were affected by wildfires, including the largely stand replacing Las Conchas fire and the mixed severity Thompson Ridge fire. The data used in this report were collected to examine the responses of mule deer to these wildfires and forest restoration treatments. The winter range is located among the foothills of the Jemez Mountains, consisting primarily of pinyon-juniper woodlands. Individuals migrated an average of 16.2 miles, either to the western edge of the Jemez Mountains, near Blue Bird Mesa, or to the Valles Caldera National Preserve. The central migration route follows the top of a 1,300-foot escarpment paralleling and eventually crossing New Mexico State Route 4 twice. The summer range is dominated by ponderosa pine and mixed-conifer forests, along with open grasslands in the Valles Caldera. The herd is only partially migratory, as resident individuals are found on the winter range and on Lake Fork Mesa, west of the caldera. State Route 4 may act as a slight obstacle to migration, as one of the larger stopover sites was located between the two road crossings.

Animal Capture and Data Collection

Sample size: 30 female mule deer

Relocation frequency: approximately 5–6 hours; 4 fixes per day

Project duration: 2012–2017

Data Analysis

Corridor, stopover, and winter range analysis: Fixed Motion Variance movement models (see app. 1 for further description of methods)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 35 sequences from 11 individuals (20 spring sequences, 15 fall sequences)
- Winter: 11 sequences from 7 individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: April 12 to April 13
- Fall: October 14 to October 16

Days migrating (mean):

- Spring: 10 days
- Fall: 6 days

Migration length:

- Minimum: 4.5 miles (7.3 km)
- Mean: 16.2 miles (26.1 km)
- Maximum: 22.6 miles (36.3 km)

Migration area:

- 80,480 acres (32,569.1 ha) (low use; 10 percent)
- 35,607 acres (14,409.6 ha) (medium use; 10–20 percent)
- 13,615 acres (5,509.8 ha) (high use; greater than 20 percent)
- Stopover area: 4,794 acres (1,940.1 ha)

Winter Range Summary

Winter start and end dates (median):

- October 16 to April 4
- Winter length (mean): 176 days
- Winter range (50 percent contour) area: 20,534 acres (8,309.8 ha)

Other Information

Project contacts:

- James W. Cain (jwcain@nmsu.edu), Assistant Unit Leader, New Mexico Cooperative Fish and Wildlife Research Unit, Department of Fish, Wildlife, and Conservation Ecology, New Mexico State University

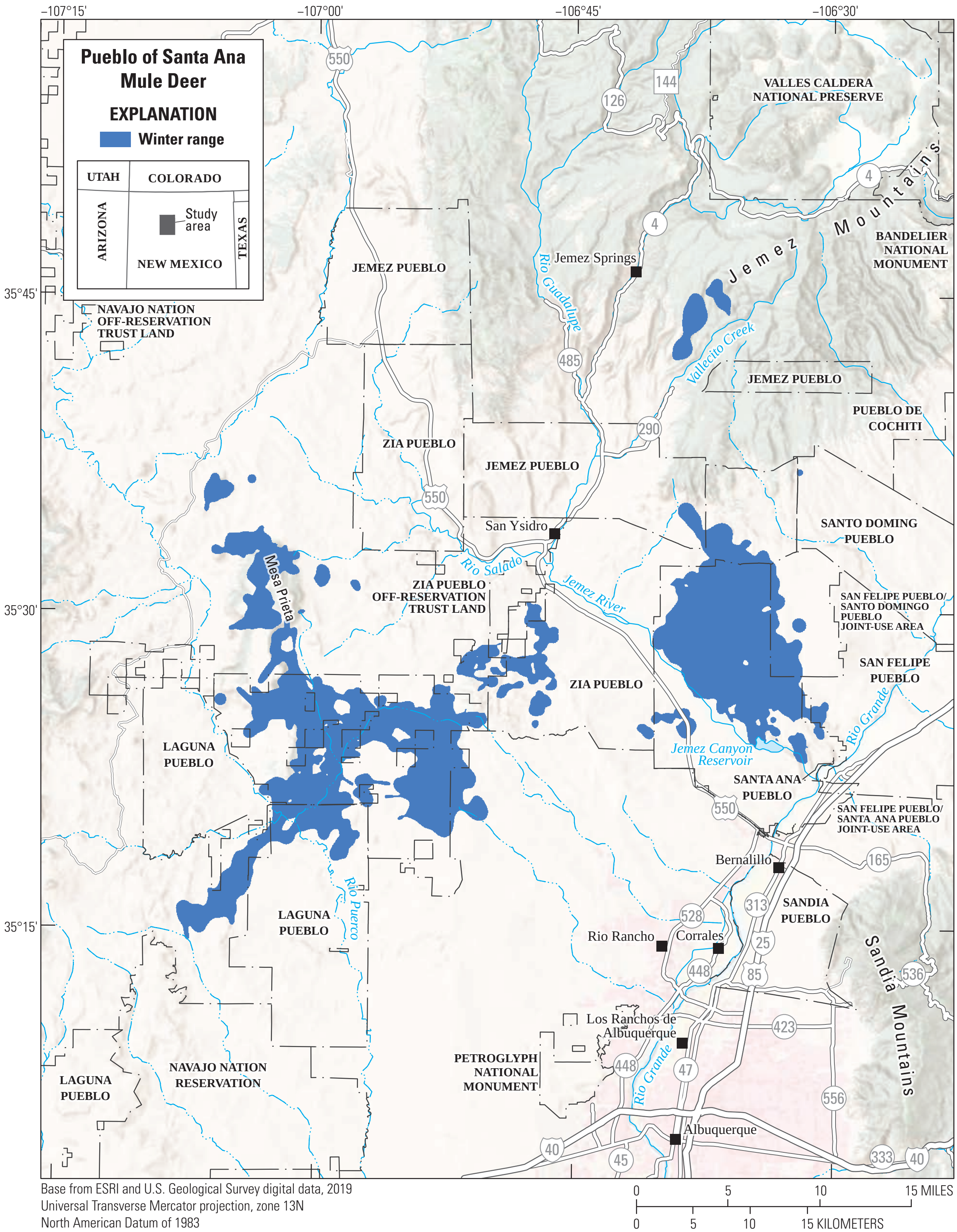
Data analyst:

- Craig Reddell, GIS Analyst, New Mexico State University

Reports and publications:

- Roerick, T.M., Cain, J.W., and Gedir, J.V., 2019, Forest restoration, wildfire, and habitat selection by female mule deer: Forest Ecology and Management, v. 447 p. 169–179.

Photograph from New Mexico State University.



Base from ESRI and U.S. Geological Survey digital data, 2019
Universal Transverse Mercator projection, zone 13N
North American Datum of 1983

Figure 24. Winter ranges of the Pueblo of Santa Ana mule deer herd.

New Mexico | Mule Deer

Pueblo of Santa Ana Mule Deer

The Pueblo of Santa Ana mule deer herds are primarily nonmigratory, with two distinct winter ranges separated by U.S. Route 550 in New Mexico (fig. 24). The winter ranges consist primarily of Chihuahuan semidesert grassland, dominated by *Bouteloua eriopoda* (Torr.) (black grama), *Pleuraphis jamesii* (Torr.) (galleta), *Sporobolus flexuosus* (mesa dropseed), and *Atriplex canescens* (fourwing saltbush), with higher elevation sections consisting of pinyon-juniper woodland and *Juniperus monosperma* (oneseed juniper) savannah. There was no movement between the two winter ranges, with only individuals from the winter range northeast of U.S. Route 550 crossing the highway west of the Jemez Canyon Reservoir. Two individuals from the winter range northeast of U.S. Route 550 migrated to the southern slopes of the Jemez Mountains. One of those individuals migrated to the winter range of the Jemez Springs herd. U.S. Route 550 and Interstate 25 to the southeast may limit movements for both herds, with any potential migration to the Jemez Mountains by individuals from the winter range southwest of U.S. Route 550 needing to cross the U.S. Route 550 and any potential migration to the Sandia Mountains by individuals from the winter range northeast of U.S. Route 550 needing to cross Interstate 25.

Animal Capture and Data Collection

Sample size: 29 adult mule deer (11 males, 18 females)
Relocation frequency: 2–4 hours, 4–8 fixes per day
Project duration: 2010–2020

Data Analysis

Winter range analysis: Brownian bridge movement models (Sawyer and others, 2009)

Delineation of migration periods: December to March (winter range)

Models derived from:

- Winter: 70,611 locations from 29 individuals

Winter Range Summary

Winter start and end dates:

- December 1 to March 1
- Winter length: 90 days
- Winter range (50 percent contour) area: 113,083 acres (45,763 ha)

Other Information

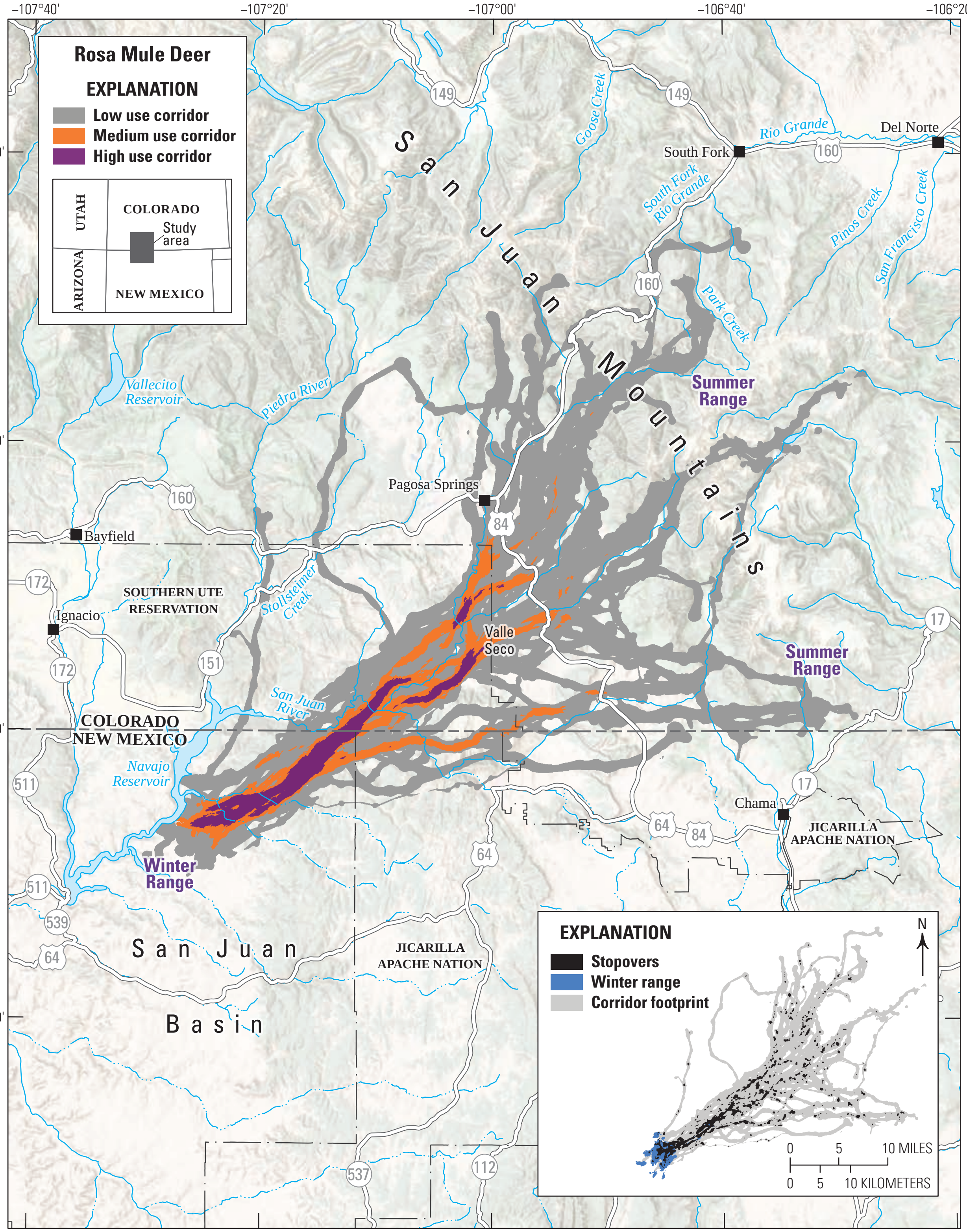
Project contacts:

- Glenn Harper (glenn.harper@santaana-nsn.gov), Range and Wildlife Division Manager, Pueblo of Santa Ana, Department of Natural Resources
- Daniel Ginter (daniel.ginter@santaana-nsn.gov), Range Program Manager, Pueblo of Santa Ana, Department of Natural Resources

Data analyst:

- Hall Sawyer, Wildlife Biologist WEST, Inc.

Photograph from Catherine Nishida, Pueblo of Santa Ana.



Base from ESRI and U.S. Geological Survey digital data, 2019
Universal Transverse Mercator projection, zone 13N
North American Datum of 1983

Figure 25. Migration corridors, stopovers, and winter ranges of the Rosa mule deer herd.

New Mexico | Mule Deer

Rosa Mule Deer

The Rosa mule deer herd migrates an average of 45 miles from northwest New Mexico to southwest Colorado (fig. 25). Their winter range is located in the upper San Juan Basin, east of the Navajo Reservoir, and is dominated by pinyon juniper woodlands and sagebrush grasslands. The Rosa herd use three distinct areas as summer range: the lower elevation Valle Seco, consisting primarily of ponderosa pine woodland and big sagebrush shrubland, and the higher elevation north and south San Juan Mountains, consisting of ponderosa pine and aspen-mixed woodlands. The herd collectively migrates northeast from their winter range for around 12 miles before a second route branches off the main corridor, with these individuals traveling to summer ranges in the Valle Seco and south San Juan Mountains. The main corridor continues for another 7 miles before splitting into three separate corridors leading into the north and south San Juan Mountains. Challenges to migration include crossing U.S. Highways 160 and 84 and increasing residential development around Pagosa Springs, Colorado. Ongoing and future energy development projects, including the drilling of well pads and use of maintenance roads, in the upper San Juan Basin may also cause disturbances to mule deer migration and their winter range.

Animal Capture and Data Collection

Sample size: 70 adult female mule deer
Relocation frequency: 2 hours; 12 fixes per day
Project duration: 2011–2018

Data Analysis

Winter range analysis: Brownian bridge movement models (Sawyer and others, 2009)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 402 sequences from 68 individuals (208 spring sequences, 194 fall sequences)
- Winter: 252 sequences from 70 individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: April 22 to May 15
- Fall: October 17 to November 1

Days migrating (mean):

- Spring: 22 days
- Fall: 16 days

Migration length:

- Minimum: 23.6 miles (38 km)
- Mean: 45.4 miles (73 km)
- Maximum: 70.8 miles (114 km)

Migration area:

- 449,051 acres (181,724.5 ha) (low use; 10 percent)
- 62,822 acres (25,423.2 ha) (medium use; 10–20 percent)
- 20,890 acres (8,453.9 ha) (high use; greater than 20 percent)
- Stopover area: 48,943 acres (19,806.5 ha)

Winter Range Summary

Winter start and end dates:

- December 1 to March 31
- Winter length: 120 days
- Winter range (50 percent contour) area: 20,951 acres (8,478.6 ha)

Other Information

Project contacts:

- Hall Sawyer (hsawyer@west-inc.com), Wildlife Biologist, WEST Inc.

Data analyst:

- Hall Sawyer, Wildlife Biologist, WEST Inc.

Reports and publications:

- Sawyer, H., LeBeau, C.W., McDonald, T.L., Xu, W., and Middleton, A.D., 2019, All routes are not created equal—An ungulate's choice of migration route can influence its survival: Journal of Applied Ecology, v. 56, no. 8, p. 1860–1869.
- Sawyer, H., 2018, Rosa mule deer study—Final Report: Laramie, Wyo., Western Ecosystems Technology, 19 p.

Photograph from New Mexico State University.

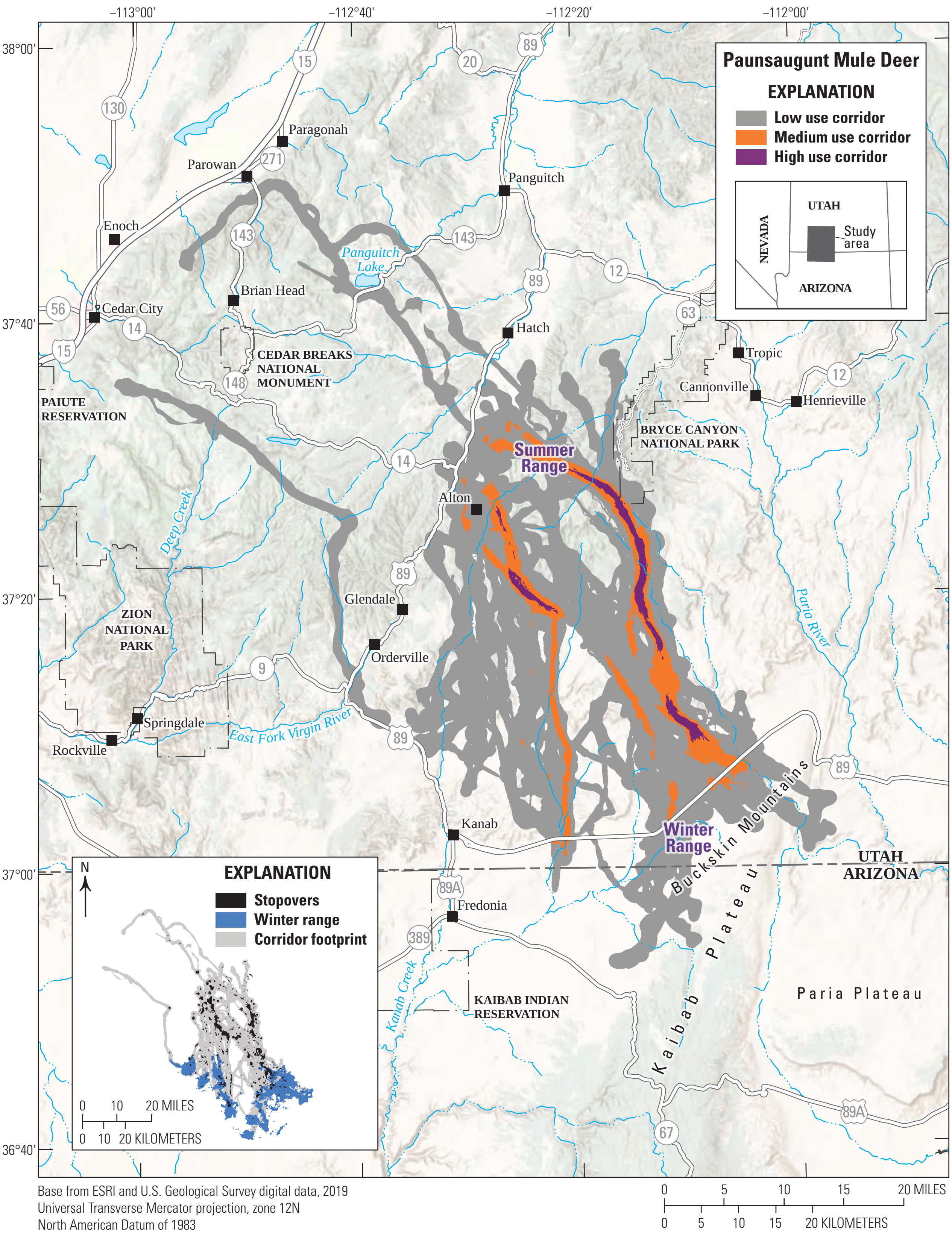


Figure 26. Migration corridors, stopovers, and winter ranges of the Paunsaugunt mule deer herd.

Utah and Arizona | Mule Deer

Paunsaugunt Mule Deer

The Paunsaugunt mule deer herd in southern Utah is estimated at 5,200 individuals. Ongoing research by the Utah DWR has continued to shape our understanding of their annual migration. In contrast to the volume 1 report (Kauffman and others, 2020a), the Paunsaugunt mule deer herd in this report includes GPS data from an additional 25 individual mule deer, 127 migrations, and 161 winter range sequences (fig. 26). Beginning in early October the mule deer migrate south an average of 36 mi (58 km) to winter range along the Utah–Arizona border. Approximately 20–30 percent of the Paunsaugunt herd reside in northern Arizona during the winter, sharing the winter range also used by mule deer from the Arizona Kaibab Plateau herd. Beginning around mid-April, the mule deer return north to their summer range on the Paunsaugunt Plateau. The most significant challenge for these mule deer is U.S. Highway 89 which bisects this migration corridor and winter range, where mule deer-vehicle collisions have historically been a problem. In 2012, the Utah Department of Transportation and partners placed 12.5 mi (20.1 km) of wildlife exclusion fence between existing and new crossing structures to reduce mule deer-vehicle collisions and provide connectivity for mule deer and other wildlife across the highway. These mitigation measures have been a tremendous success, facilitating more than 78,600 successful mule deer crossings and a 77 percent crossing success rate (Cramer and Hamlin, 2019).

Animal Capture and Data Collection

Sample size: 79 adult mule deer (39 male, 40 female)
Relocation frequency: 2 hours
Project duration: 2017–present

Data Analysis

Corridor, stopover, and winter range analysis: Brownian bridge movement models (Sawyer and others, 2009)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 244 sequences from 77 individuals (135 spring sequences, 109 fall sequences)
- Winter: 197 sequences from 79 individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: April 21 to April 28
- Fall: October 6 to October 17

Days migrating (mean):

- Spring: 11 days
- Fall: 12 days

Migration length:

- Minimum: 10 mi (16 km)
- Mean: 38 mi (61 km)
- Maximum: 80 mi (129 km)

Migration area:

- 499,809 acres (202,270 ha) (low use)
- 339,787 acres (137,510 ha) (medium use)
- 57,278 acres (23,180 ha) (high use)
- Stopover area: 51,570 acres (20,870 ha)

Winter Range Summary

Winter start and end dates (median):

- October 17 to April 21
- Winter length (mean): 185 days
- Winter range (50 percent contour) area: 138,425 acres (564,020 ha)

Other Information

Project contacts:

- Daniel Olson (danielolson@utah.gov), Wildlife Migration Initiative Coordinator, Utah Department of Natural Resources

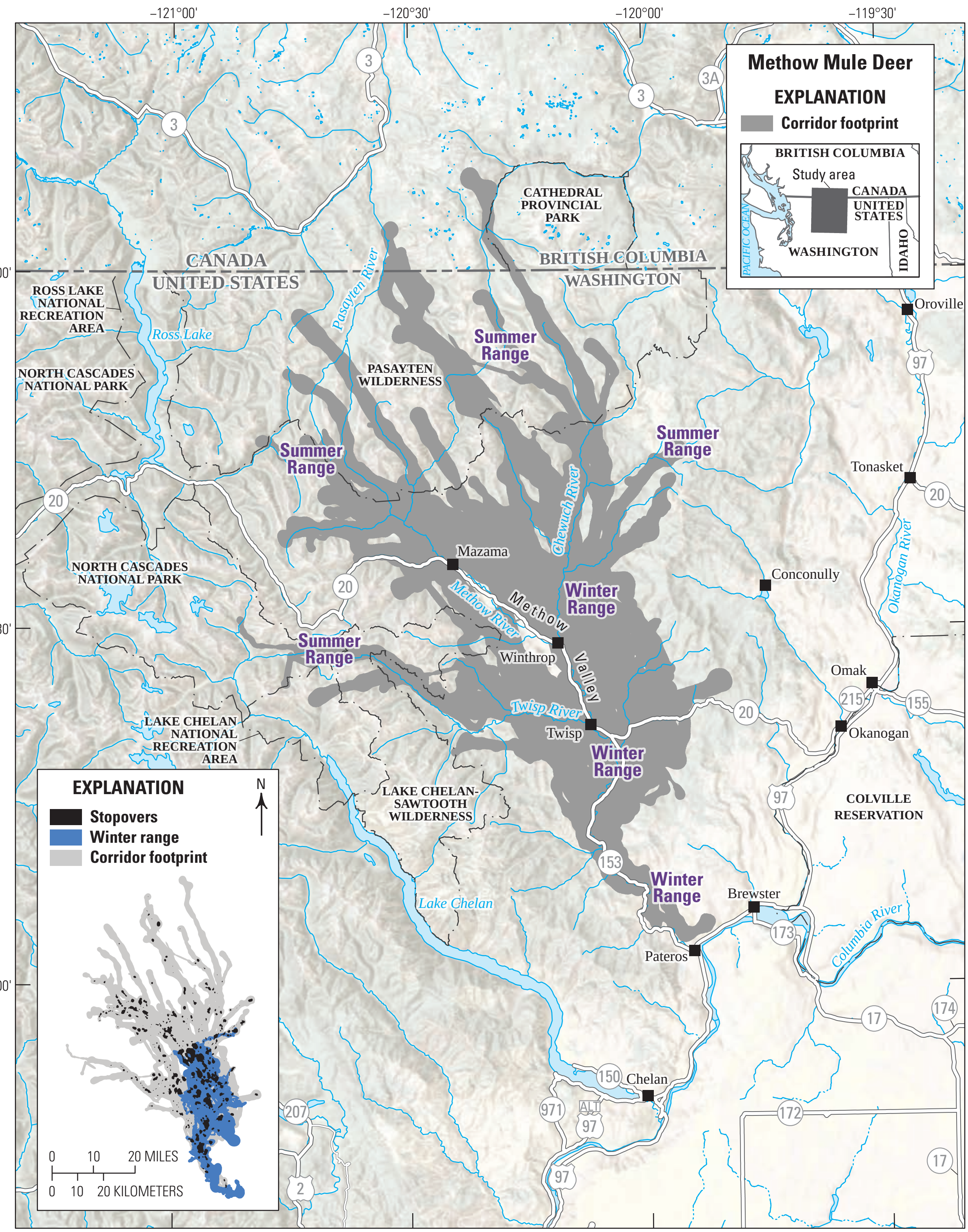
Data analyst:

- Lucas Olson, Cooperative Mule Deer Biologist, Mule Deer Foundation and Arizona Game and Fish Department

Reports and publications:

- Carrel, W.K., Ockenfels, R.A., and Schweinsburg, R.E., 1999, An evaluation of annual migration patterns of the Paunsaugunt mule deer herd between Utah and Arizona: Phoenix, Ariz., Arizona Game and Fish Department, Research Branch Tech. Rep. No. 29. 44 p.
- Cramer, P., and Hamlin, R., 2019, US 89 Kanab-Paunsaugunt wildlife crossing and existing structures research project—Final report, Taylorsville, Utah, Utah Department of Transportation, 88 p. [Also Available at https://drive.google.com/file/d/1Afa51pEELIcja5aKUqFla3m7dCjJUuGQ/view.]
- Hendricks, C, 2001, Mule deer habitat use of the Buckskin Mountain winter range: Logan, Utah, Utah State University, master's thesis, 68 p.
- Messmer, T., and Klimack, P., 1999, Summer habitat use and migration movements of the Paunsaugunt Plateau mule deer herd: Salt Lake City, Utah, Utah Division of Wildlife Resources, 79 p.

Photograph from P. Cramer, Utah Department of Transportation, Utah Department of Wildlife Resources, and Arizona Game and Fish Department.



Base from ESRI and U.S. Geological Survey digital data, 2019
Universal Transverse Mercator projection, zone 10 N
North American Datum of 1983

Figure 27. Migration corridors, stopovers, and winter ranges of the Methow mule deer herd.

Washington | Mule Deer

Methow Mule Deer

The Methow mule deer subherd is part of the larger West Okanogan mule herd, the largest migratory mule deer herd in Washington. Individuals travel as far as 65 miles twice annually between the lowland winter range and the higher elevation summer range (fig. 27). Mule deer wintering on the shrubsteppe dominated foothills in the lower half of the Methow River valley undertake a roughly 3-week trek in midspring to the productive subalpine and alpine meadows of the Pasayten and Lake Chelan-Sawtooth Wilderness areas, and surrounding high country, with some animals traveling north into British Columbia, Canada. On summer range they mingle with mule deer moving up from the west side of the Okanogan valley forming an estimated summering population of 15,000–25,000 animals. Migrating mule deer in the Methow River watershed do not have to contend with any known major barriers, but their movements are somewhat constrained in the lower portion of the watershed where the topography narrows the valley considerably.

Animal Capture and Data Collection

Sample size: 128 adult female mule deer
Relocation frequency: 4 hours
Project duration: 2017–2020

Data Analysis

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011).

Models derived from:

- Migration: 321 sequences from 97 individuals (201 spring sequences, 120 fall sequences)
- Winter: 262 sequences from 126 individuals

Route Summary

Migration start and end dates (median):

- Spring: April 24 to May 16
- Fall: October 14 to October 23

Days migrating (mean):

- Spring: 22 days
- Fall: 14 days

Migration route length:

- Minimum: 2.93 mi (4.7 km)
- Mean: 28.90 mi (46.5 km)
- Maximum: 65.00 mi (104.6 km)

Migration corridor area:

- 1,160,999 acres (469,840 ha) (low use)
- Stopover area: 71,634 acres (28,989 ha)

Winter Use Summary of Collared Individuals

Winter use start and end dates (median):

- January 20 to March 18
- Winter use length (mean): 64 days
- Winter range (50 percent contour) area: 95,529 acres (38,659 ha)

Other Information

Project contacts:

- Brock Hoenes (Brock.Hoenes@dfw.wa.gov) Ungulate Section Manager, Washington Dept of Fish and Wildlife
- Scott Fitkin (Scott.Fitkin@dfw.wa.gov) Okanogan District Biologist, Washington Dept of Fish and Wildlife

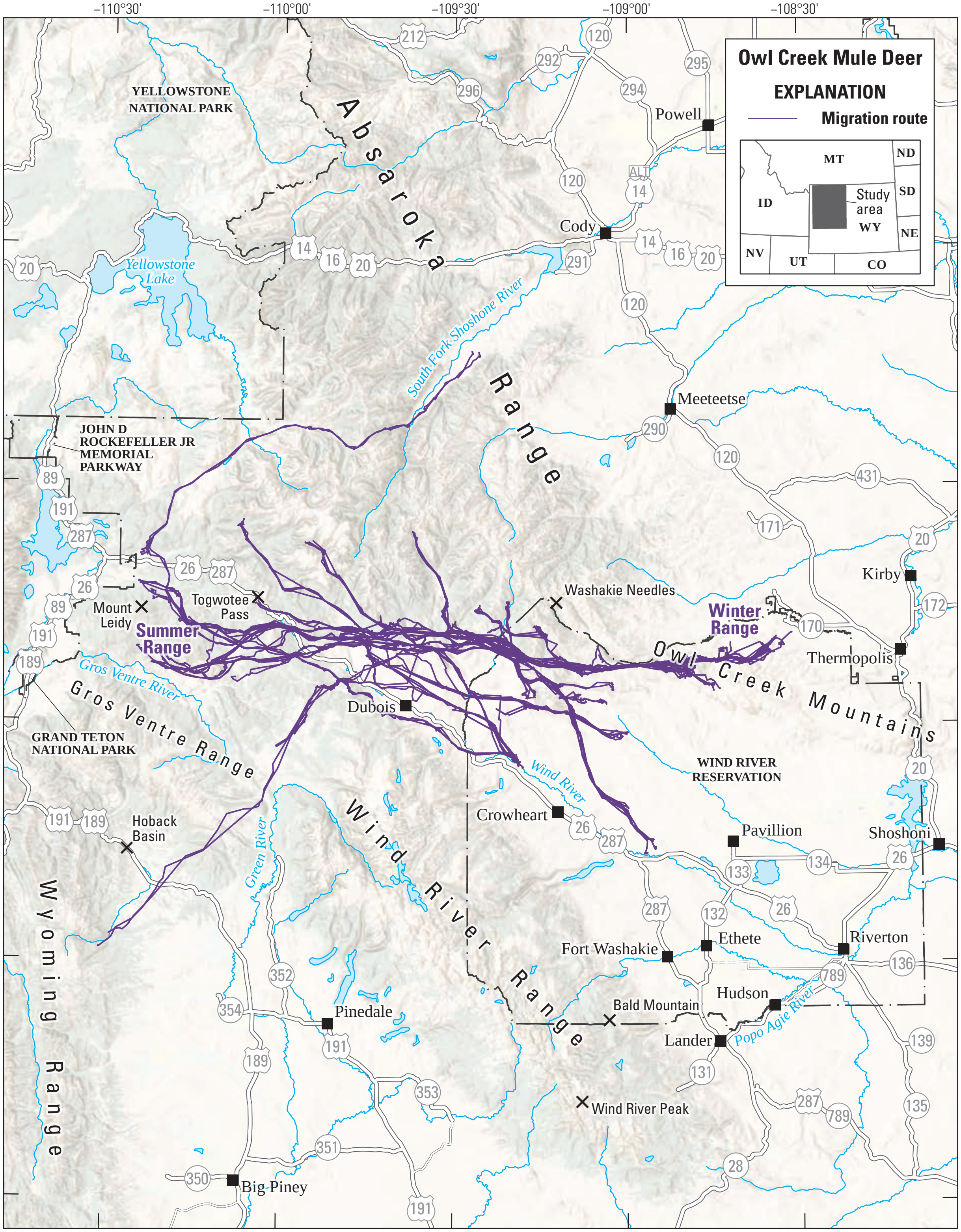
Data analyst:

- Julien Fattebert, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming

Reports and publications:

- Washington Department of Fish and Wildlife, 2016, Washington State mule deer management plan: Wildlife Program, Olympia, Wash.,Washington Department of Fish and Wildlife, 144 p.
- Washington Department of Fish and Wildlife, 2020 Game status and trend report: Wildlife Program, Olympia, Wash., Washington Department of Fish and Wildlife, 407 p. [Also available at https://wdfw.wa.gov/sites/default/files/publications/02217/wdfw02217.pdf.]

Photograph from Scott Fitkin, Washington Department of Fish and Wildlife.



Base from ESRI, U.S. Geological Survey, National Park Service, and U.S. Census Bureau digital data, 2019
Universal Transverse Mercator projection, zone 12N
North American Datum of 1983

0 10 20 30 40 MILES
0 10 20 30 40 KILOMETERS

Figure 28. Migration routes of the Owl Creek Mountains mule deer herd.

Wind River Indian Reservation | Mule Deer

Owl Creek Mountains Mule Deer

The mule deer herd along the Owl Creek Mountains display both a longitudinal and altitudinal migration as they depart the northern section of the Wind River Indian Reservation (fig. 28). Mule deer in this transboundary migration corridor move from areas under the jurisdiction and sovereignty of the Eastern Shoshone and Northern Arapaho, to lands where the Wyoming Game and Fish Department manages wildlife. West of the reservation, mule deer migrate to summer ranges in the Absaroka Range, Mount Leidy, and the Gros Ventre River watershed, all within the Bridger-Teton and Shoshone National Forests. The herd numbers around 3,000. Arid winter ranges are a mix of shrubs, herbaceous grasslands and riparian ecosystems, within Tribal land as well as private land along the Wind River. Animals migrate an average one-way distance of 63 mi (101 km), ranging from as little as 14 mi (23 km) to as far as 141 mi (227 km). Summer ranges are predominantly lodgepole pine forests with smaller areas of open herbaceous grasslands. The herd population size remained relatively steady since approximately 2010. There is minimal concern for these animals on winter range because Tribal Trust Land is at low risk of development, and the Eastern Shoshone and Northern Arapaho manage mule deer hunting for sustainable harvest through a game code established in 1984. However, some of their winter range along Wind River is in close proximity to U.S. Highway26/287, putting mule deer at heightened risk of vehicle collisions. Critically, the migration routes extend through residential areas such as the Dubois and the Hoback Basin with heightened risk of negative human-wildlife interactions (for example, vehicle collisions, fences, and barriers). Risks in summer ranges within national forests are of less concern.

Animal Capture and Data Collection

Sample size: 20 adult female mule deer
Relocation frequency: 2 hours
Project duration: 2018–2021

Data Analysis

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011).

Models derived from:

- Migration: 73 sequences from 20 individuals (37 spring sequences, 36 fall sequences)
- Winter: 52 sequences from 20 individuals

Route Summary

Migration start and end dates (median):

- Spring: May 22 to June 6
- Fall: October 12 to November 3

Days migrating (mean):

- Spring: 19 days
- Fall: 24 days

Migration route length:

- Minimum: 13.9 mi (22.4 km)
- Mean: 62.6 mi (100.7 km)
- Maximum: 141.2 mi (227.2 km)

Winter Use Summary

Winter use start and end dates (median):

- November 5 to May 24
- Days of winter use (mean): 191 days

Other Information

Project contacts:

- Art Lawson (Lawson@windriverfishandgame.com), Director Shoshone and Arapaho Fish and Game Department
- Pat Hnilicka (pat_hnilicka@fws.gov), Project Leader, U.S. Fish and Wildlife, Lander Conservation Office Service
- Matthew Kauffman (mkauffm1@uwyo.edu), U.S. Geological Survey, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming

Data analyst:

- Julien Fattebert, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming

Photograph from Mark Gocke, Wyoming Game and Fish Department.

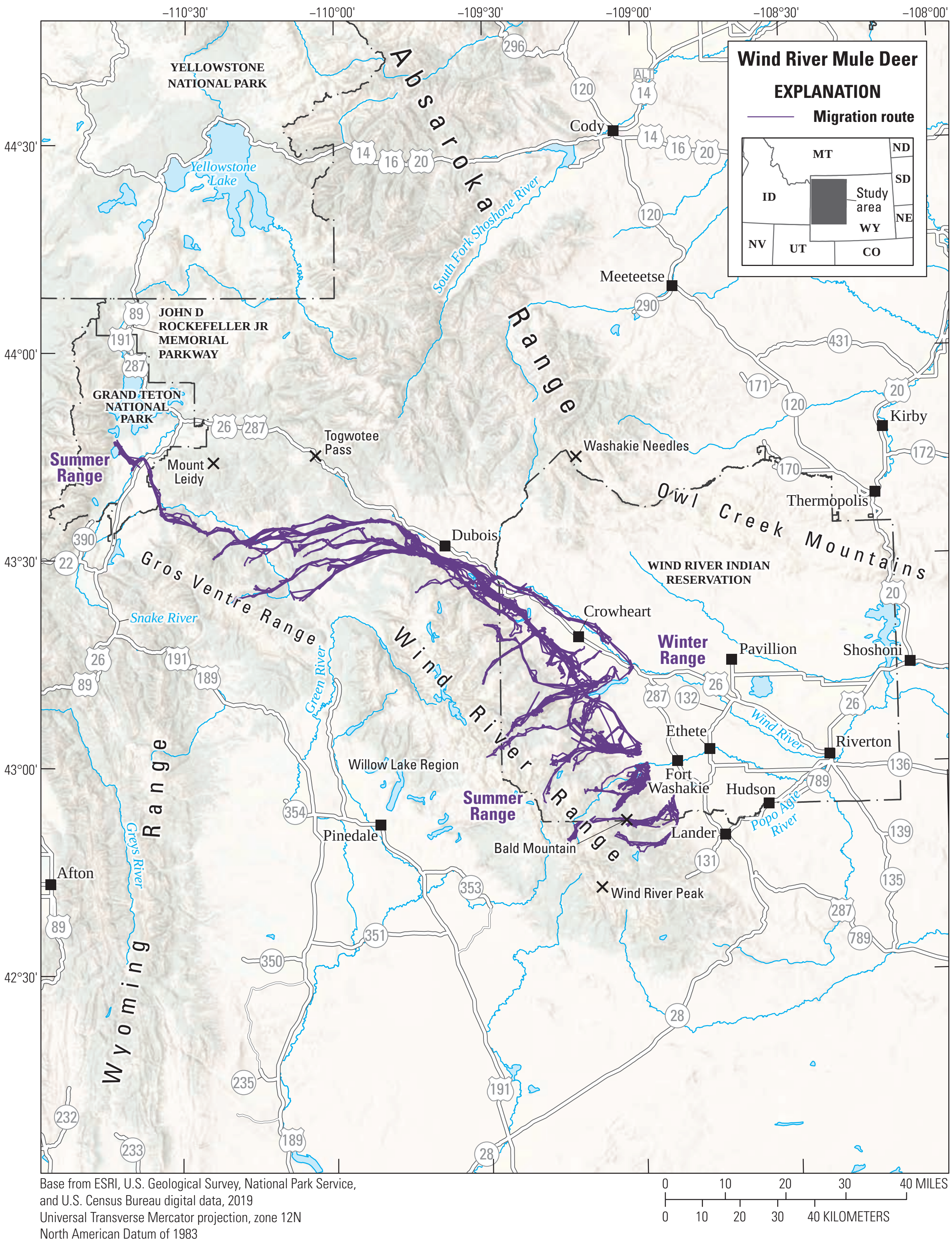


Figure 29. Migration routes of the Wind River mule deer herd.

Wind River Indian Reservation | Mule Deer

Wind River Mule Deer

Some of the Wind River mule deer herd in the southwestern section of the reservation are unique, because their entire migration routes are within Eastern Shoshone and Northern Arapaho lands (fig. 29). In the spring, mule deer migrate from the foothills of the Wind River Range upslope to the Wind River roadless area, or northwest into the Shoshone and Bridger-Teton National Forests or Grand Teton National Park, demonstrating how the reservation is part of the Greater Yellowstone Ecosystem. The herd, which numbers around 1,500, winters entirely within the reservation from the western boundary of the reservation to south of Fort Washakie. Winter habitats consist of upland shrubs, sagebrush, grasses, and riparian areas. Summer ranges are largely lodgepole pine forests, mountain meadows, and alpine areas. Animals migrate an average one-way distance of 29 mi (47 km) ranging from as short as 4 mi (6 km) to as far as 131 mi (211 km). The population has been stable since the early 2000s. Winter ranges of these animals are largely secure under management by Shoshone and Arapaho Tribes Game and Fish, and Tribal policies limiting where rural housing and development can occur. The migration routes are a more serious concern because some are relatively long, and U.S. Highway 26/287 is one of the highest-priority areas in the state for reducing wildlife-vehicle collisions (Wyoming Wildlife and Roadways Initiative, 2019). Additionally, a portion of the population moves through residential subdivisions near Dubois. Once the mule deer reach summer range, the habitats are under Federal management, and aside from timber harvest and grazing, the land is largely free from development.

Animal Capture and Data Collection

Sample size: 71 adult female mule deer
Relocation frequency: 2 hours
Project duration: 2018–2021

Data Analysis

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011).

Models derived from:

- Migration: 152 sequences from 48 individuals (83 spring sequences, 69 fall sequences)
- Winter: 122 sequences from 61 individuals

Route Summary

Migration start and end dates (median):

- Spring: May 24 to June 4
- Fall: October 25 to November 5

Days migrating (mean):

- Spring: 19 days
- Fall: 26 days

Migration route length:

- Minimum: 3.8 mi (6.1 km)
- Mean: 28.9 mi (46.5 km)
- Maximum: 131.4 mi (211.5 km)

Winter Use Summary

Winter use start and end dates (median):

- November 6 to May 24
- Days of winter use (mean): 168 days

Other Information

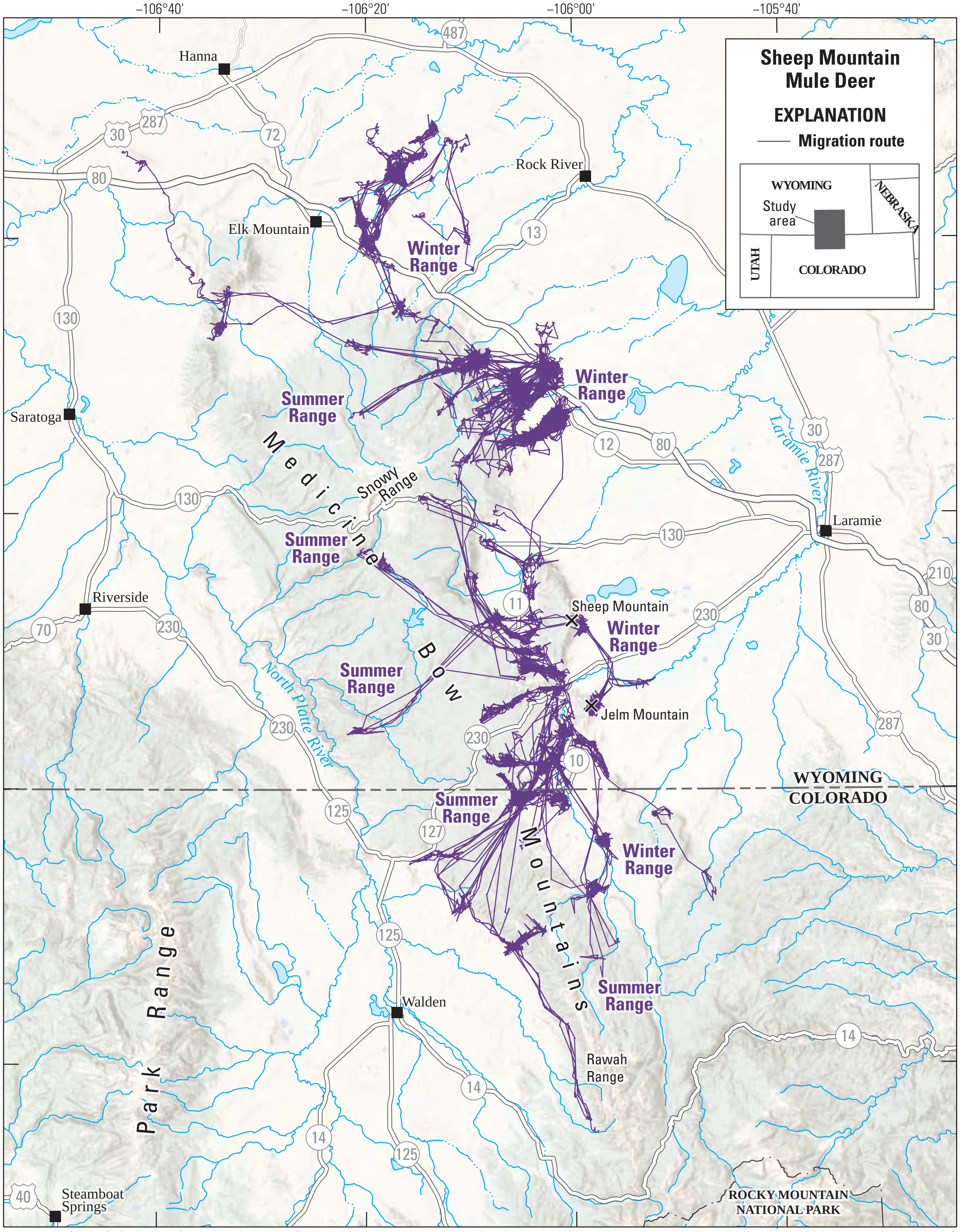
Project contacts:

- Art Lawson (Lawson@windriverfishandgame.com), Director Shoshone and Arapaho Fish and Game Department
- Pat Hnilicka (pat_hnilicka@fws.gov), Project Leader, U.S. Fish and Wildlife Service
- Matthew Kauffman (mkauffm1@uwyo.edu), U.S. Geological Survey, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming

Data analyst:

- Julien Fattebert, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming

Photograph from Mark Gocke, Wyoming Game and Fish Department.



Base from ESRI, U.S. Geological Survey, National Park Service, and U.S. Census Bureau digital data, 2019
Universal Transverse Mercator projection, zone 13N
North American Datum of 1983

0 5 10 15 20 MILES
0 5 10 15 20 KILOMETERS

Figure 30. Migration routes of the Sheep Mountain mule deer herd.

Wyoming | Mule Deer

Sheep Mountain Mule Deer

The Sheep Mountain mule deer herd winters in the east and northeast foothills of the Snowy Range in southeastern Wyoming (fig. 30). The Sheep Mountain herd is mainly migratory with few individuals staying on the winter range year round. Winter ranges are a mix of grassland and sagebrush hills often free of snow from wind. During migration, animals tracked with GPS collars (56 females) travel an average one-way distance of nearly 20 miles (32 km), with some animals migrating more than 50 miles (80 km). The herd (approximately 7,600) has a variety of summer destinations. Some individuals migrate across the Snowy Range to the west. Others migrate into Colorado, summering in the Rawah Range. Others migrate short distances into higher elevation foothills of the Snowy Range. Many individuals traverse the eastern front of the Snowy Range, particularly west of Sheep Mountain and west and southwest of Jelm Mountain. Summer ranges generally consist of lodgepole pine forests intermixed with aspen and riparian habitats. The forests of these summer ranges have been severely affected by bark beetle during the last 20 years. More recently, large forest fires have burned some of the summer ranges of this herd. Fawn recruitment most years meets the bare minimum needed for the population to remain stable. The majority of the herd residing north of Wyoming Highway 130 crosses Interstate 80 to access winter range. Successfully crossing Interstate 80 is essential to the persistence of these segments of the herd. Some crossing locations have been successfully mitigated but most have not. Besides Interstate 80, urban development of private lands on winter range is a concern. Much of this herd's summer range is on USFS and BLM lands, but most of their winter range is on private lands. In the southern portion of this herd there has been an expansion of housing development built in critical winter range habitats, which removes critical forage, adds stress, as well as increases disease transmission because of homeowners feeding wildlife.

Animal Capture and Data Collection

Sample size: 56 adult female mule deer
Relocation frequency: 2 hours
Project duration: 2017–2019

Data Analysis

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011).

Models derived from:

- Migration: 166 sequences from 56 individuals (91 spring sequences, 75 fall sequences)

Route Summary

Migration start and end dates (median):

- Spring: May 2 to May 27
- Fall: October 12 to December 10

Days migrating (mean):

- Spring: 37 days
- Fall: 44 days

Migration route length:

- Minimum: 1.2 mi (1.9 km)
- Mean: 18.8 mi (30.3 km)
- Maximum: 50.5 mi (81.3 km)

Other Information

Project contacts:

- Lee Knox, Wyoming Game and Fish Department
- Embere Hall, Wyoming Game and Fish Department

Data analyst:

- Lee Knox, Wyoming Game and Fish Department

Photograph from Mark Gocke, Wyoming Game and Fish Department.

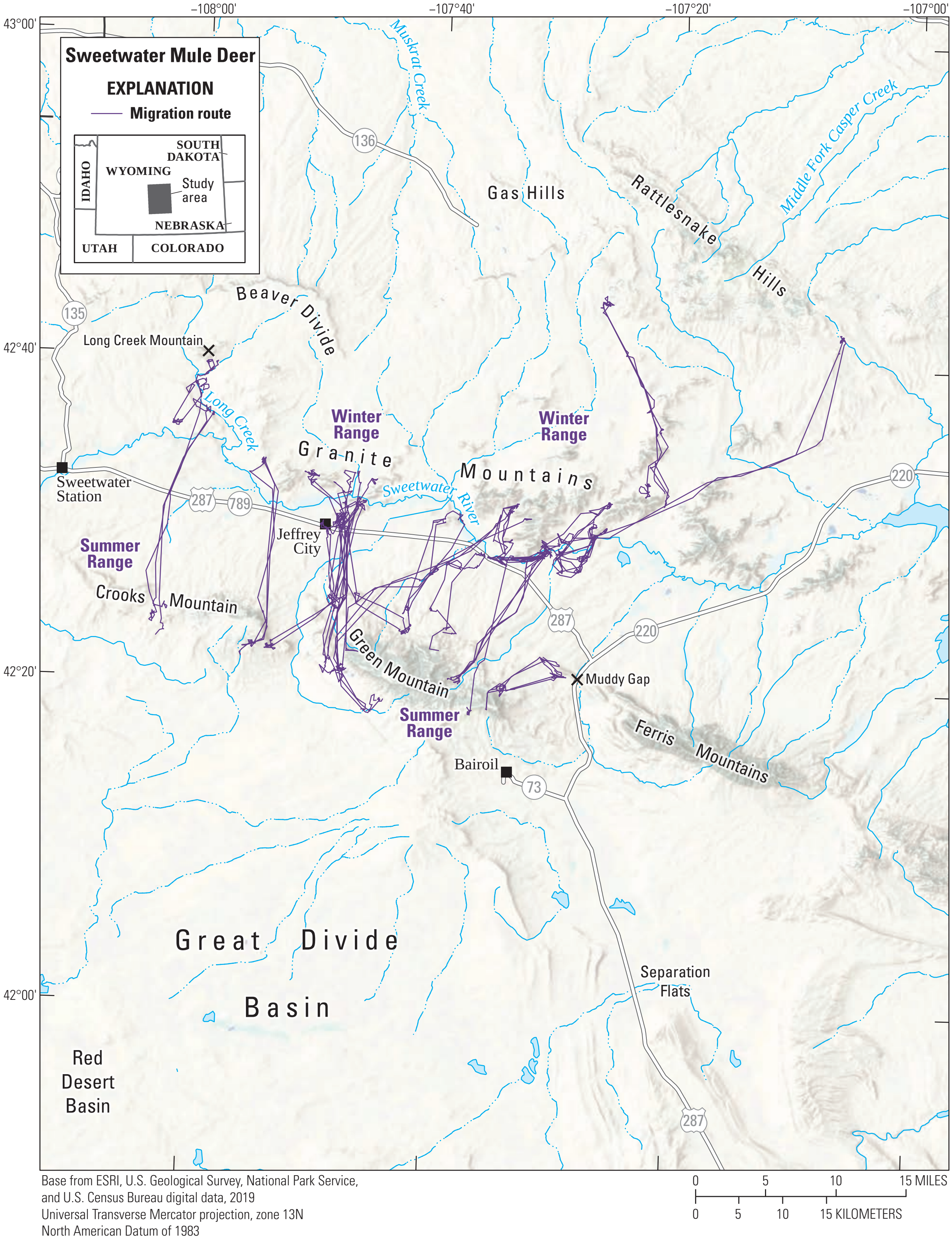


Figure 31. Migration routes of the Sweetwater mule deer herd.

Wyoming | Mule Deer

Sweetwater Mule Deer

The Sweetwater mule deer herd display mostly a latitudinal migration though the seasonal direction varies among individuals in the population (fig. 31). The migration route is between Long Creek Mountain and Granite Mountains in the north and the Green Mountains in the south. In the spring, the majority of the population descends from the southern foothills of Granite Mountains and heads south to the Green Mountains. Some individuals, however, will move the opposite direction and migrate from south to north. Additionally, movement between the two areas can also occur outside of the typical spring or fall migration. The herd, which numbers around 3,700, primarily winters along the northern section, ranging from Long Creek Mountain and Granite Mountain. Some individuals, however, will winter along the northern foothills of the Green Mountains. Winter and summer ranges consist mainly of shrubs, such as sagebrush, and are located on both private and BLM land. In both winter and summer, the herd tends to avoid the higher elevations consisting primarily of evergreen forests. During migration animals travel an average one-way distance of 14 mi (23 km) ranging from as little as 5 mi (8 km) to as far as 28 mi (45 km). The population size of the herd has remained relatively steady since 2015, though harsh winters will lead to a marked decrease in annual survival. While the migration routes are relatively short, there are still some management concerns, namely movement between the northern and southern section crosses U.S. Highway 287, which could lead to increased collisions with motorists. Additionally, much of their migration route as well as their winter and summer ranges, are located within private land.

Animal Capture and Data Collection

Sample size: 27 adult female mule deer
Relocation frequency: 2 hours
Project duration: 2018–2020

Data Analysis

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 55 sequences from 21 individuals (31 spring sequences, 24 fall sequences)
- Winter: 40 sequences from 25 individuals

Route Summary

Migration start and end dates (median):

- Spring: April 19 to April 23
- Fall: November 29 to December 3

Days migrating (mean):

- Spring: 5 days
- Fall: 5 days

Migration route length:

- Minimum: 5.2 mi (8.4 km)
- Mean: 13.7 mi (22.0 km)
- Maximum: 28.0 miles (45.1 km)

Winter Use Summary

Winter use start and end dates (median):

- January 01 to March 14
- Days of winter use (mean): 68 days

Other Information

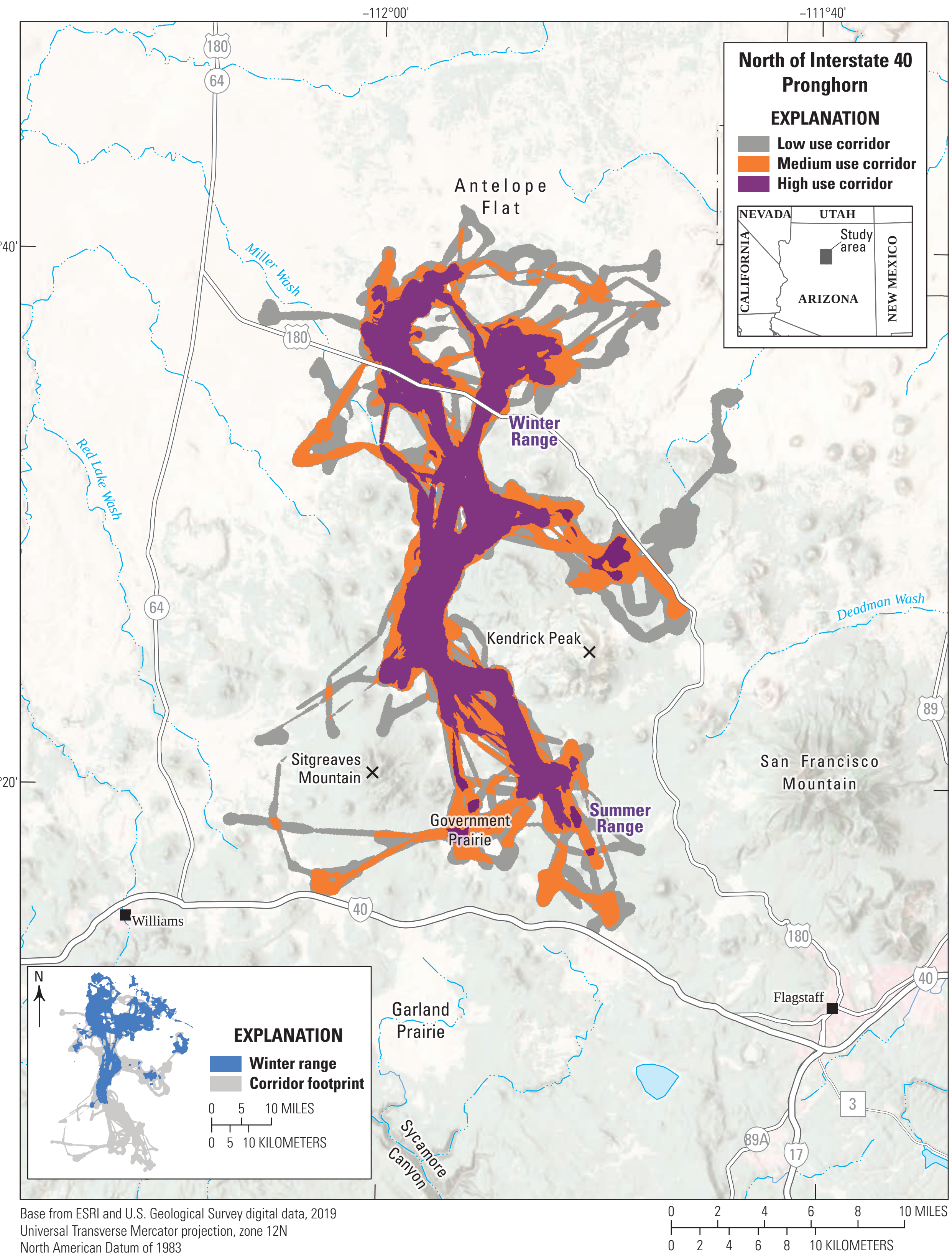
Project contacts:

- Daryl Lutz (daryl.lutz@wyo.gov), Wildlife Management Coordinator, Wyoming Game and Fish Department
- Stan Harter (stan.harter@wyo.gov), Wildlife Biologist, Wyoming Game and Fish Department

Data analyst:

- Julien Fattebert, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming.

Photograph from Mark Gocke, Wyoming Game and Fish Department.



Base from ESRI and U.S. Geological Survey digital data, 2019
Universal Transverse Mercator projection, zone 12N
North American Datum of 1983

Figure 32. Migration corridors and winter ranges of the North of Interstate 40 pronghorn herd.

Arizona | Pronghorn

North of Interstate 40 Pronghorn

The North of Interstate 40 pronghorn herd primarily resides in Arizona's GMU 7. GMU 7 had an estimated population of 550 pronghorn in 2019. The herd summers in high elevation open meadows and ponderosa pine habitat near Government Prairie (fig. 32). When winter conditions set in, the pronghorn seek lower elevations, migrating through mixed pinyon-juniper woodlands to open grassland and shrub habitats north of Sitgreaves Mountain, often crossing U.S. Highway 180 (US-180) towards Antelope Flat. US-180 is an increasing threat to this migration corridor as traffic volumes rise. However, right-of-way fence improvements and relatively low traffic volumes on US-180 allow some degree of permeability across this highway. Additionally, encroaching pinyon-juniper woodlands are a threat to open grassland habitat within both summer and winter range.

Animal Capture and Data Collection

Sample size: 16 adult pronghorn (7 male, 9 female)
Relocation frequency: approximately 2 hours, 8 fixes per day
Project duration: 2014–2017

Data Analysis

Corridor, stopover, and winter range analysis: Brownian bridge movement models (Sawyer and others, 2009); corridor analysis used Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 65 sequences from 16 individuals (32 spring sequences, 33 fall sequences)
- Winter: 27 sequences from 14 individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: February 14 to March 6
- Fall: November 26 to December 17

Days migrating (mean):

- Spring: 18 days
- Fall: 23 days

Migration corridor length:

- Minimum: 10 mi (16 km)
- Mean: 38 mi (61 km)
- Maximum: 89 mi (143 km)

Migration corridor area:

- 126,738 acres (51,290 ha) (low use)
- 79,863 acres (32,320 ha) (medium use)
- 43,811 acres (17,730 ha) (high use)

Winter Range Summary

Winter start and end dates (median):

- December 18 to February 13
- Winter length (mean): 74 days
- Winter range (50 percent contour) area: 79,912 acres (32,340 ha)

Other Information

Project contacts:

- Jeff Gagnon (jgagnon@azgfd.gov), Wildlife Specialist Regional Supervisor, Arizona Game and Fish Department
- Scott Sprague (ssprague@azgfd.gov), Project Manager/Road Ecologist, Arizona Game and Fish Department

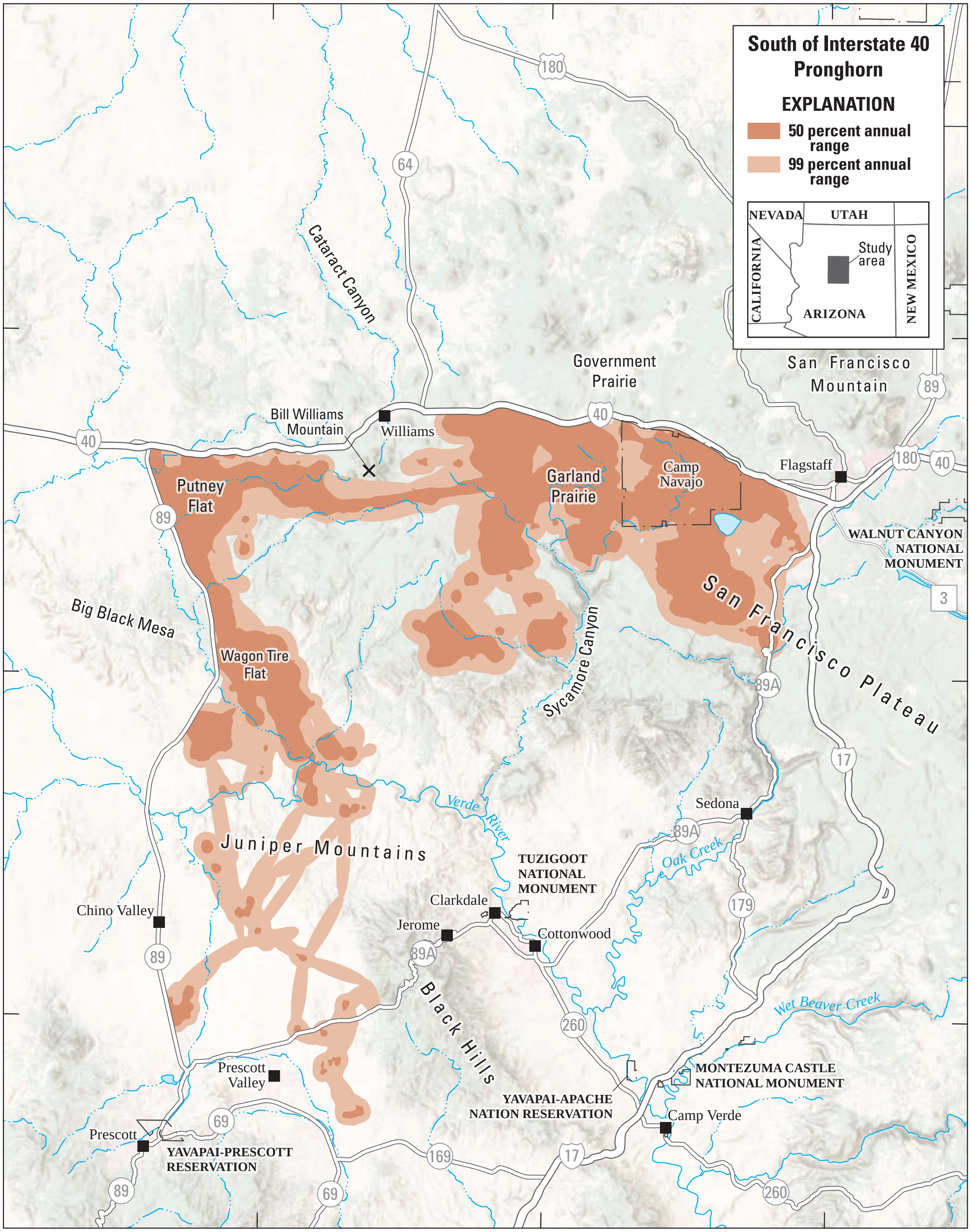
Data analyst:

- Lucas Olson, Cooperative Mule Deer Biologist, Mule Deer Foundation and Arizona Game and Fish Department

Reports and publications:

- Dodd, N.L., Gagnon, J.W., Sprague, S.C., Boe, S., and Schweinsburg, R.E., 2011, Assessment of pronghorn movements and strategies to promote highway permeability—U.S. Highway 89: Phoenix, Ariz., Arizona Department of Transportation Research Center, Final project report 619, 84 p. [Also available at https://azdot.gov/content/assessment-pronghorn-movements-and-strategies-promote-highway-permeability-us-highway-89.]
- Theimer, T., Sprague, S.C., Eddy, E., and Benford, R., 2012, Genetic variation of pronghorn across US Route 89 and State Route 64: Phoenix, Ariz., Arizona Department of Transportation, Final report 659, 43 p. [Also available at https://rosap.ntl.bts.gov/view/dot/23984.]

Photograph from George Andrejko, Arizona Game and Fish Department.



Base from ESRI and U.S. Geological Survey digital data, 2019
Universal Transverse Mercator projection, zone 12N
North American Datum of 1983

0 5 10 15 MILES
0 5 10 15 KILOMETERS

Figure 33. Winter ranges of the South of Interstate 40 pronghorn herd.

Arizona | Pronghorn

South of Interstate 40 Pronghorn

The South of Interstate 40 pronghorn herd make one of Arizona's most remarkable migrations. This herd resides primarily in GMU 8, which had a population estimate of 450 individuals in 2019. Unlike traditional summer-winter range dynamics, this pronghorn herd relies on a complex of several important seasonal ranges connected by narrow corridors (fig. 33). Migration between ranges appear to be driven by winter conditions, thus, the timing of the movements is highly variable. The herd has high fidelity to these corridors, which elevates the importance of research and management efforts to conserve them. During the summer, these pronghorn inhabit large grasslands in and around Garland Prairie. During migration, animals move westward, parallel to Interstate 40 passing through densely forested habitat before stopping on grasslands in Putney Flat. After some time there, many individuals move even lower in elevation, traveling south to winter range on Wagon Tire Flat and open meadows north of the Verde River. Some individuals cross the Verde River, traveling through the Juniper Mountains as far south as U.S. Highway 69. High-volume roads including Interstate 40 and State Route 89 present the largest threats to movement for this herd. These roads also appear to affect the herd's movement patterns along this corridor, as pronghorn rarely cross them.

Animal Capture and Data Collection

Sample size: 24 adult pronghorn (6 male, 18 female)

Relocation frequency: approximately 2 hours, 8 fixes per day

Project duration: 2018–present

Data Analysis

Annual range analysis: Brownian bridge movement models (Horne and others, 2007; see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Annual Range: 43 sequences from 24 individuals

Annual Range Summary

Migration corridor length:

- Minimum: 20 mi (32 km)
- Mean: 60 mi (97 km)
- Maximum: 118 mi (190 km)
- Annual range (50 percent contour) area: 205,439 acres (83,140 ha)
- Annual range (99 percent contour) area: 407,048 acres (164,730 ha)

Other Information

Project contacts:

- Jeff Gagnon (jgagnon@azgfd.gov), Wildlife Specialist Regional Supervisor, Arizona Game and Fish Department
- Scott Sprague (ssprague@azgfd.gov), Project Manager and Road Ecologist, Arizona Game and Fish Department

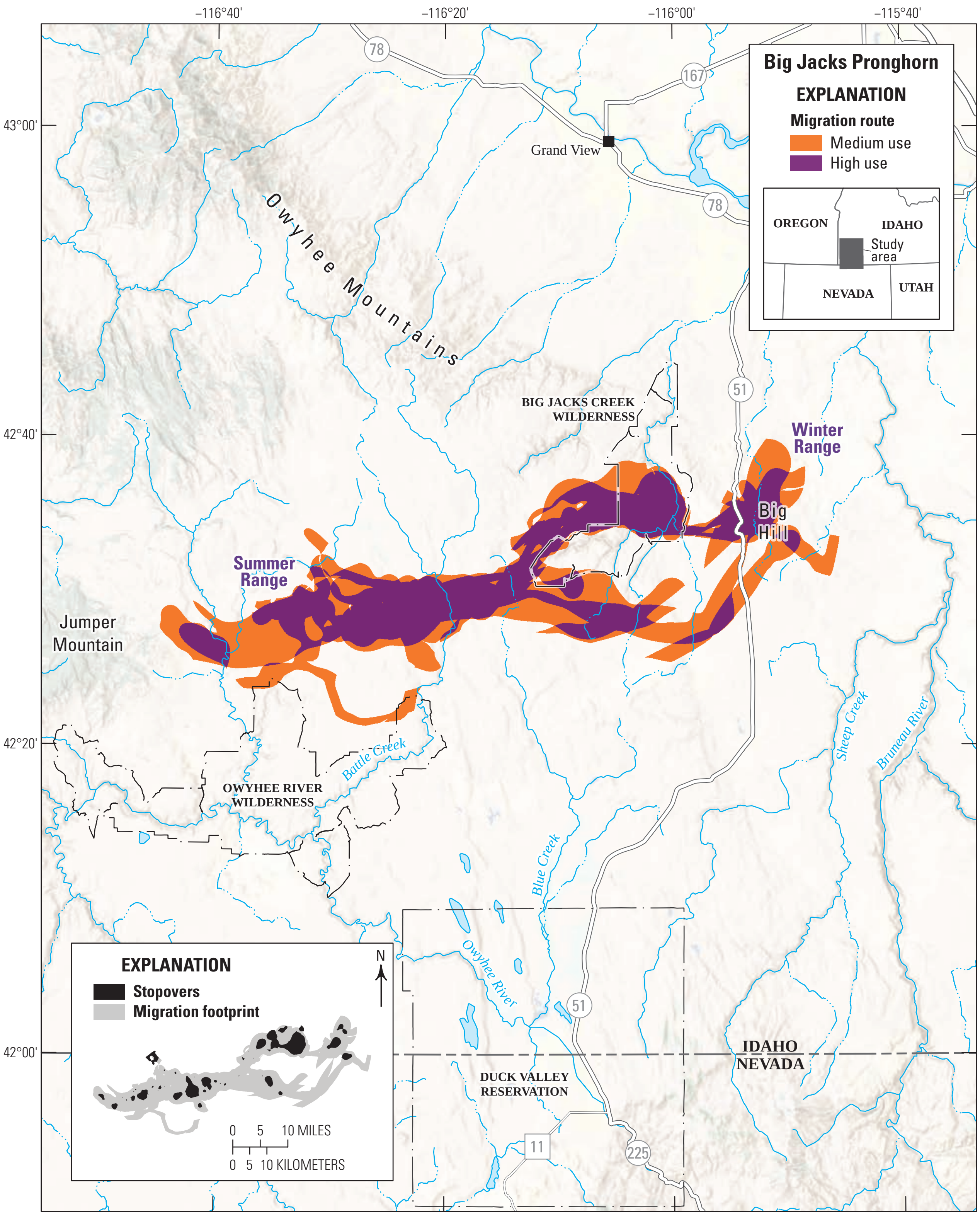
Data analyst:

- Lucas Olson, Cooperative Mule Deer Biologist, Mule Deer Foundation and Arizona Game and Fish Department

Reports and publications:

- Dodd, N.L., Gagnon, J.W., Sprague, S.C., Boe, S. and Schweinsburg, R.E., 2011, Assessment of pronghorn movements and strategies to promote highway permeability—U.S. Highway 89: Phoenix, Ariz., Arizona Department of Transportation Research Center, Final project report 619, 84 p. [Also available at https://azdot.gov/content/assessment-pronghorn-movements-and-strategies-promote-highway-permeability-us-highway-89.]
- Theimer, T., Sprague, S.C., Eddy, E., and Benford, R., 2012, Genetic variation of pronghorn across US Route 89 and State Route 64 final report 659: Phoenix, Ariz., Arizona Department of Transportation, 43 p. [Also available at https://rosap.ntl.bts.gov/view/dot/23984.]

Photograph from Tammy Reed, On-Site Photography.



Base from ESRI and U.S. Geological Survey digital data, 2019
Universal Transverse Mercator projection, zone 11N
North American Datum of 1983

Figure 34. Migration routes and stopovers of the Big Jacks pronghorn herd.

Idaho | Pronghorn

Big Jacks Pronghorn

The winter Big Jacks pronghorn herd is centered in the vicinity of Big Jacks Creek Wilderness Area and Big Hill in southwestern Idaho. The migration route follows a route from the southwest to arid tables just north of the Owyhee River Wilderness Area at the foothills of Jumper Mountain (fig. 34). The Big Jacks herd faces future challenges associated with wildfire converting sage steppe habitats into invasive cheatgrass flats.

Animal Capture and Data Collection

Sample size: 12 female pronghorn
Relocation frequency: approximately 2 hours
Project duration: April 2019–December 2020

Data Analysis

Annual range analysis: Brownian bridge movement models (Sawyer and others 2009; see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011) where start of the biological year was set to peak fawning date.

Models derived from:

- Migration: 16 sequences from 12 individuals (4 spring sequences, 12 fall sequences)

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: April 6 to April 23
- Fall: October 7 to October 31

Days migrating (mean):

- Spring: 17 days
- Fall: 25 days

Migration length:

- Min: 9 mi (14 km)
- Mean: 55 mi (89 km)
- Maximum: 139 mi (224 km)

Migration area:

- 199,231 acres (80,626 ha) (medium use; 10–20 percent)
- 104,461 acres (42,274 ha) (high use; greater than 20 percent)
- Stopover use: 31,629 acres (12,800 ha)

Other Information

Project contacts:

- Mark Hurley (mark.hurley@idfg.idaho.gov), Wildlife Research Supervisor, Idaho Department of Fish and Game
- Ryan Walrath (ryan.walrath@idfg.idaho.gov), Regional Wildlife Manager, Idaho Department of Fish and Game

Data analyst:

- Scott Bergen, Senior Wildlife Research Biologist, Idaho Department of Fish and Game

Reports and publications:

- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game, 49 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/ID%20F16AF00908%20Statewide%20Wildlife%20Research%20Report%20FY18.pdf.]

Photograph from Rachel Curtis, Idaho Department of Fish and Game.

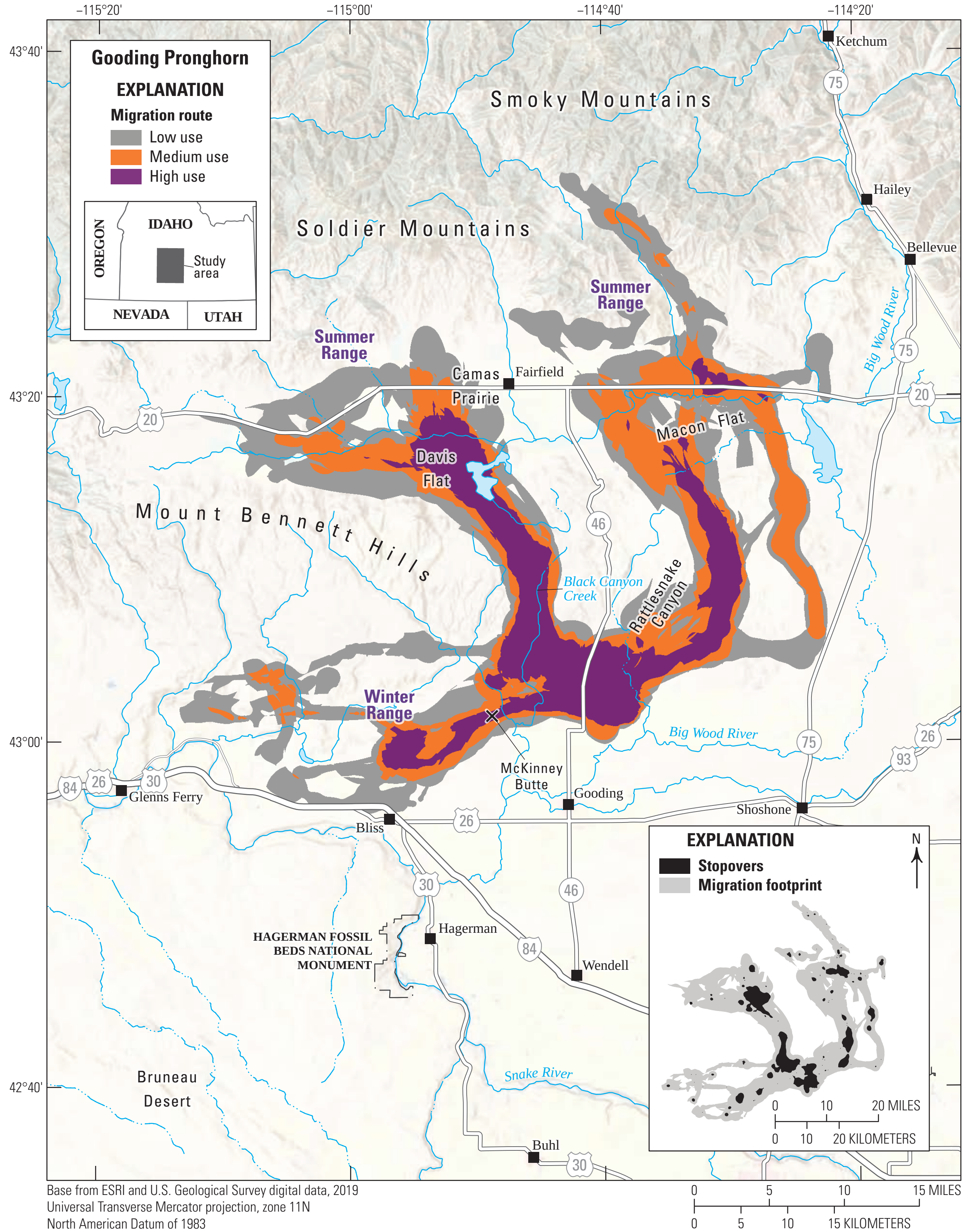


Figure 35. Migration routes and stopovers of the Gooding pronghorn herd.

Idaho | Pronghorn

Gooding Pronghorn

The winter range is extensive for the Gooding Pronghorn winter herd, which is capable of moving large distances within this range (more than 10 miles), but in essence is centered on the plateaus west of McKinney Butte in Idaho (fig. 35). The seasonal migration route travels from this location to the east where it breaks into two distinct routes. The first route follows to the west of Black Canyon Creek, skirting the Mount Bennett Hills to the west and onto the Davis Flats section of the Camas Prairie. The second branch travels east past Rattlesnake Canyon and crosses the Mount Bennett Hills onto the Macon Flat section of the Camas Prairie. Summer range is centered on the Camas Prairie where agriculture and sage steppe systems meet the front range of the Soldier Mountains. The ancient seasonal migration route of this winter herd may be threatened by wildlife unfriendly fencing, wildfire, residential development, and increased energy developments.

Animal Capture and Data Collection

Sample size: 32 female pronghorn
Relocation frequency: approximately 2 hours
Project duration: March 2019–November 2020

Data Analysis

Annual range analysis: Brownian bridge movement models (Sawyer and others 2009; see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011) where anchor date is set to peak fawning date.

Models derived from:

- Migration: 69 sequences from 32 individuals (24 spring sequences, 45 fall sequences)

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: March 27 to April 13
- Fall: October 30 to November 12

Average number of days migrating:

- Spring: 18 days
- Fall: 13 days

Migration length:

- Minimum: 19 mi (31 km)
- Mean: 44 mi (71 km)
- Maximum: 102 mi (164 km)

Migration area:

- 372,401 acres (150,705 ha) (low use; 10 percent)
- 188,615 acres (76,330 ha) (medium use; 10–20 percent)
- 85,863 acres (34,748 ha) (high use; greater than 20 percent)
- Stopover use: 4,172 acres (21,923 ha)

Other Information

Project contacts:

- Mark Hurley (mark.hurley@idfg.idaho.gov), Wildlife Research Supervisor, Idaho Department of Fish and Game
- Ryan Walrath and Mike McDonald (mike.mcdonald@idfg.idaho.gov), Regional Wildlife Manager, Idaho Department of Fish and Game

Data analyst:

- Scott Bergen, Senior Wildlife Research Biologist, Idaho Department of Fish and Game

Reports and publications:

- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game, 49 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/ID%20F16AF00908%20Statewide%20Wildlife%20Research%20Report%20FY18.pdf.]

Photograph from Idaho Department of Fish and Game.

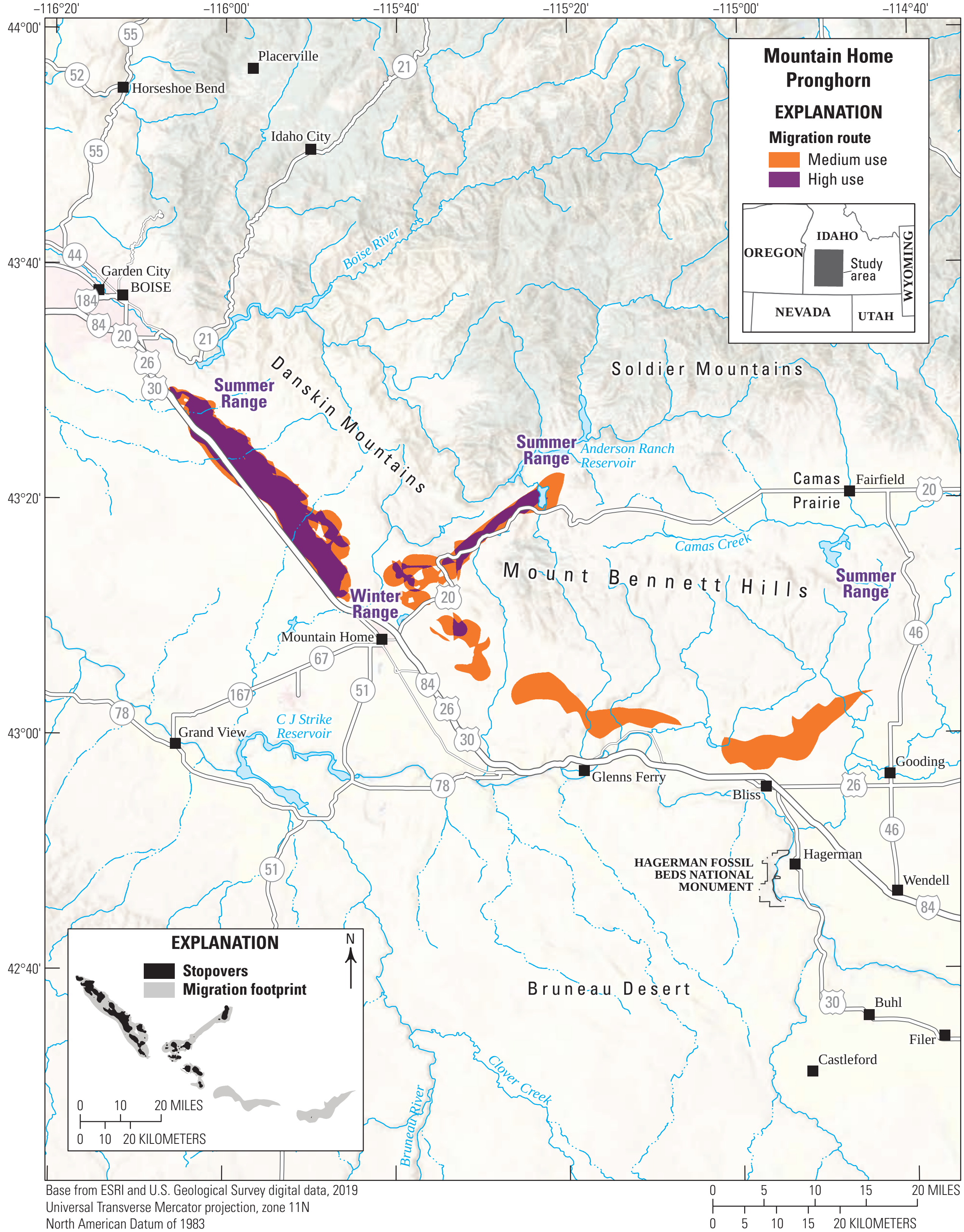


Figure 36. Migration routes and stopovers of the Mountain Home pronghorn herd.

Idaho | Pronghorn

Mountain Home Pronghorn

The Mountain Home pronghorn winter herd is probably the most visible herd in Idaho because of its proximity to Boise and being bounded to the south by Interstate 84 (fig. 36). This herd also exhibits winter movements that can exceed 10 miles presumably to move to better snow conditions. The seasonal migration route appears to go in several directions. The first migration route extends to the west almost to the city limits of Boise. The second migration route extends towards the north-east through the western edge of the Mount Bennett Hills to sage steppe habitat surrounding the Anderson Ranch Reservoir. The third migration route follows the front range of the Mount Bennett Hills to the east where pronghorn use the same migration routes as the Gooding pronghorn herd over the Mount Bennett Hills and into the eastern Camas Prairie. Pronghorn navigate a sage steppe system degraded by wildfire and invasive cheatgrass and dissected by wildlife unfriendly fence lines. Future challenges are energy developments (hydroelectric and solar), expanding human developments in this high growth area of Idaho, and wildfires.

Animal Capture and Data Collection

Sample size: 15 female pronghorn
Relocation frequency: approximately 2 hours
Project duration: March 2019–November 2020

Data Analysis

Annual range analysis: Brownian bridge movement models (Sawyer and others 2009; see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011) where start of the biological year was set to peak fawning date.

Models derived from:

- Migration: 29 sequences from 15 individuals (11 spring sequences, 18 fall sequences)

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: March 17 to April 2
- Fall: November 30 to December 9

Average number of days migrating:

- Spring: 10 days
- Fall: 9 days

Migration length:

- Minimum: 2 mi (3.5 km)
- Mean: 26 mi (42 km)
- Maximum: 73 mi (117 km)

Migration area:

- 141,962 acres (57,450 ha) (medium use; 10–20 percent)
- 138,735 acres (21,607 ha) (high use; greater than 20 percent)
- Stopover area: 38,575 acres (15,610 ha)

Other Information

Project contacts:

- Mark Hurley (mark.hurley@idfg.idaho.gov), Wildlife Research Supervisor, Idaho Department of Fish and Game
- Mike McDonald (mike.mcdonald@idfg.idaho.gov), Regional Wildlife Manager, Idaho Department of Fish and Game

Data analyst:

- Scott Bergen, Senior Wildlife Research Biologist, Idaho Department of Fish and Game

Reports and publications:

- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game, 49 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/ID%20F16AF00908%20Statewide%20Wildlife%20Research%20Report%20FY18.pdf.]

Photograph from Rachel Curtis, Idaho Department of Fish and Game.

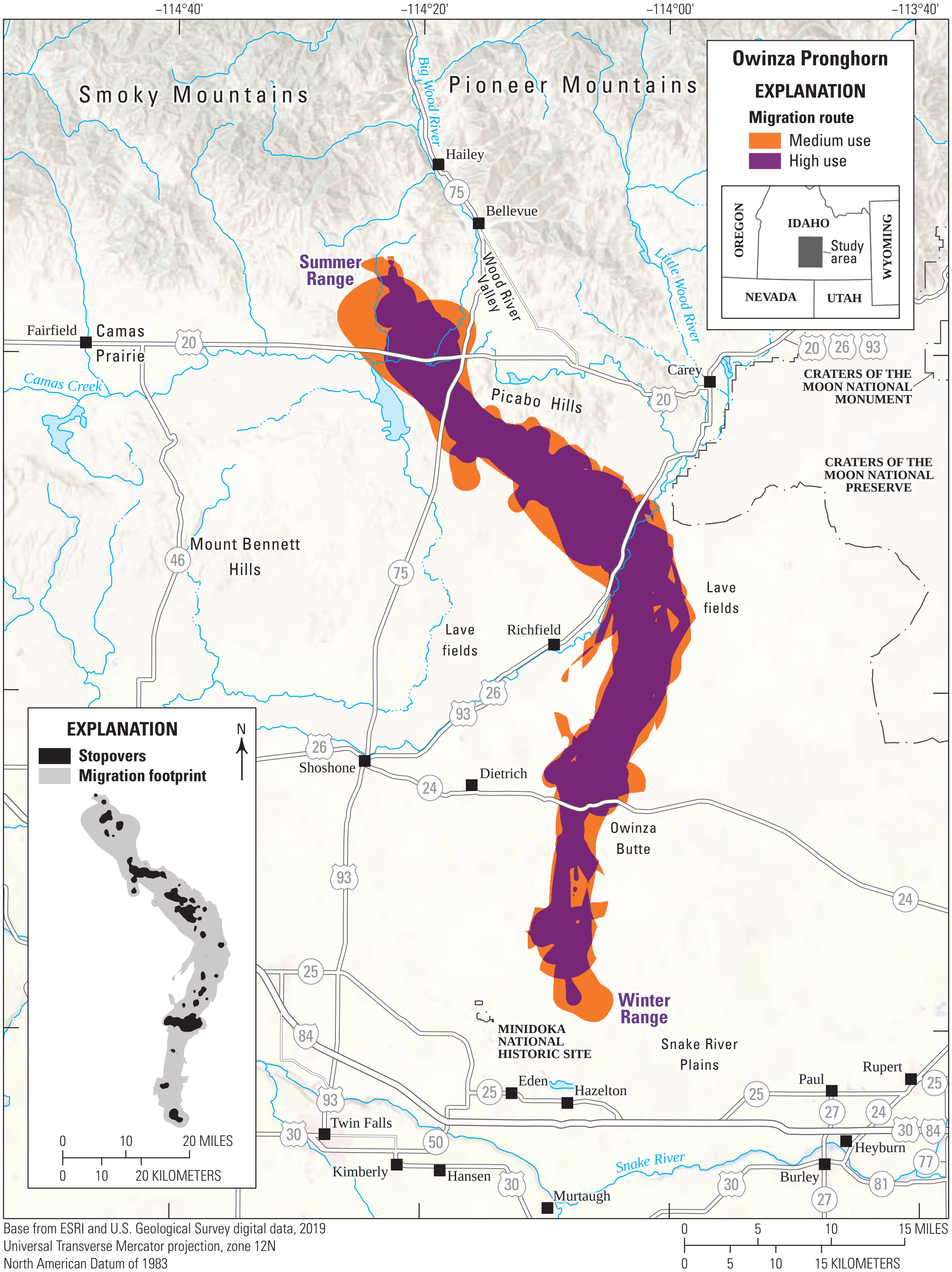


Figure 37. Migration routes and stopovers of the Owinza pronghorn herd.

Idaho | Pronghorn

Owinza Pronghorn

The Owinza pronghorn winter herd migrates by weaving through lava fields below the Mount Bennett Hills and further to the east in the Snake River Plains in Idaho (fig. 37). The seasonal migration moves north, traversing the Picabo Hills into the eastern side of Camas Prairie and west side of the Wood River Valley. This summer range is shared with members of the Gooding herd to the west. Wildlife unfriendly fencing, lava fields, and vehicular traffic endanger the ability of the herd to conduct this seasonal migration. Wildfire and the subsequent invasion of cheatgrass further degrade natural habitat. Future housing development in the Wood River Valley and associated energy developments are likely to challenge the longevity of this seasonal migration.

Animal Capture and Data Collection

Sample size: 11 female pronghorn
Relocation frequency: approximately 2 hours
Project duration: October 2019–November 2020

Data Analysis

Annual range analysis: Brownian bridge movement models (Sawyer and others 2009; see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011) where anchor date is set to peak fawning date.

Models derived from:

- Migration: 16 sequences from 11 individuals (3 spring sequences, 13 fall sequences)

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: March 18 to April 3
- Fall: November 2 to November 14

Average number of days migrating:

- Spring: 17 days
- Fall: 12 days

Migration length:

- Minimum: 33 mi (53 km)
- Mean: 57 mi (92 km)
- Maximum: 103 mi (166 km)

Migration area:

- 190,225 acres (76,981 ha) (medium use; 10–20 percent)
- 138,735 acres (56,144 ha) (high use; greater than 20 percent)
- Stopover use: 31,468 acres (12,735 ha)

Other Information

Project contacts:

- Mark Hurley (mark.hurley@idfg.idaho.gov), Wildlife Research Supervisor, Idaho Department of Fish and Game
- Mike McDonald (mike.mcdonald@idfg.idaho.gov), Regional Wildlife Manager, Idaho Department of Fish and Game

Data analyst:

- Scott Bergen, Senior Wildlife Research Biologist, Idaho Department of Fish and Game

Reports and publications:

- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game, 49 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/ID%20F16AF00908%20Statewide%20Wildlife%20Research%20Report%20FY18.pdf.]

Photograph from Idaho Department of Fish and Game.

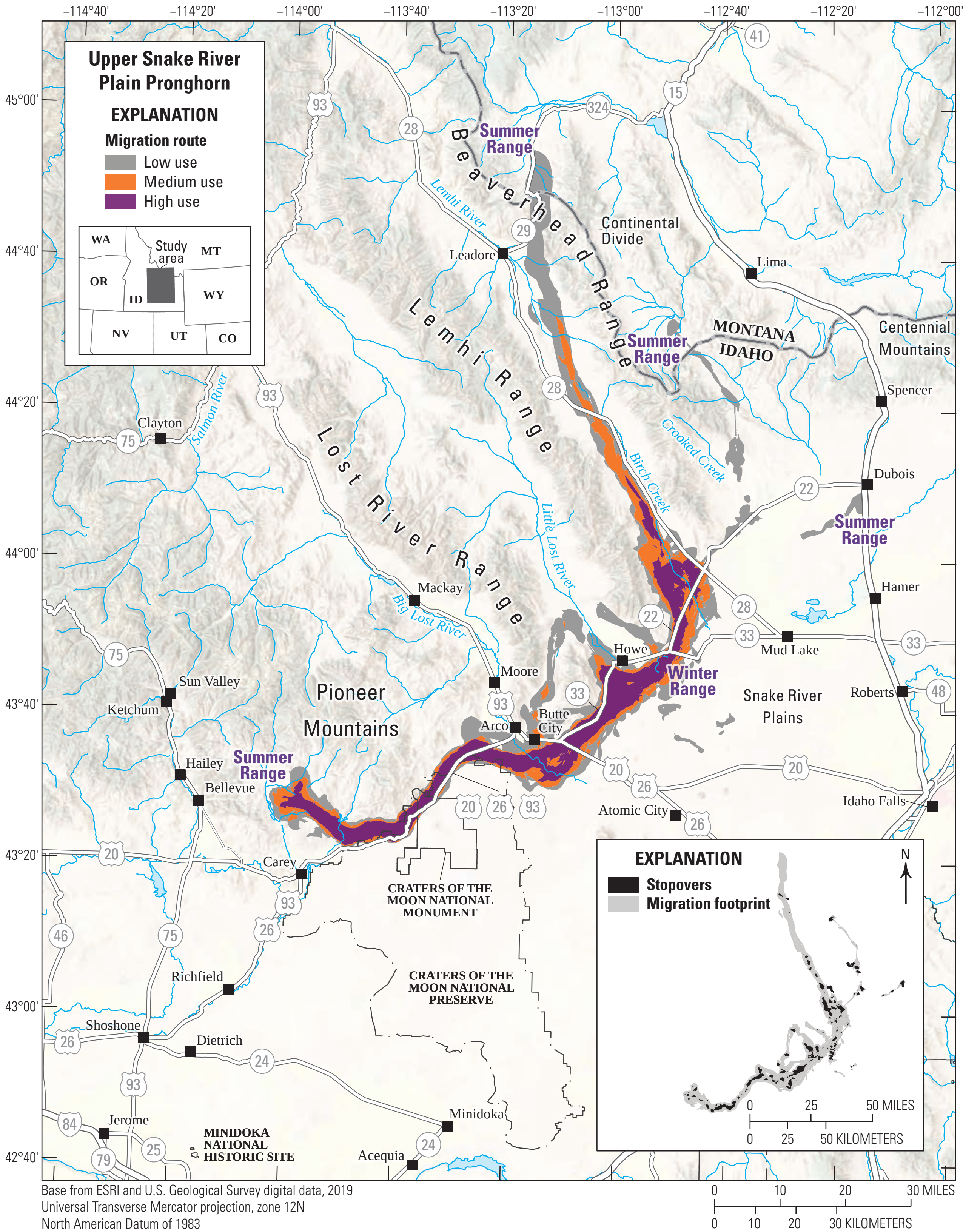


Figure 38. Migration routes and stopovers of the Upper Snake River Plain pronghorn herd.

Idaho | Pronghorn

Upper Snake River Plain Pronghorn

The winter range supports several summer pronghorn herds radiating from core winter habitat where the Snake River Plains meets the mountain valley system of Idaho (fig. 38). This region from Howe to Crooked Creek is windswept, keeping snow depth minimal. From this central location, herds migrate across the Continental Divide into several regions in Montana, higher elevation sage steppe system in Idaho, as well as the surrounding Snake River Plain. Historically, summer herds also migrated to the east towards higher elevations near the vicinity of Island Park Resevoir. Seasonal migrations still occur at great distances, especially to higher elevation habitats securing better forage and precipitation during the hot summer months. Far from secure, pronghorn encounter many fence lines, fire burn scars, invasive cheatgrass, and natural barriers such as lava flows, to reach these more fertile summer ranges. Future challenges to these migrations include energy developments (solar and wind farm) and expansion of irrigated agriculture.

Animal Capture and Data Collection

Sample size: 33 female pronghorn
Relocation frequency: approximately 3–4 hours
Project duration: October 2004–November 2011

Data Analysis

Annual range analysis: Brownian bridge movement models (Sawyer and others 2009; see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011) where anchor date is set to peak fawning date

Models derived from:

- Migration: 51 sequences from 33 individuals (25 spring sequences, 26 fall sequences)

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: March 24 to April 25
- Fall: October 10 to October 31

Average number of days migrating:

- Spring: 32 days
- Fall: 20 days

Migration length:

- Minimum: 30.5 mi (49 km)
- Mean: 84 mi (142 km)
- Maximum: 136 mi (218 km)

Migration area:

- 275,391 acres (111,447 ha) (low use; 10 percent)
- 114,266 acres (46,242 ha) (medium use; 10–20 percent)
- 166,030 acres (67,190 ha) (high use; greater than 20 percent)
- Stopover use: 95,998 acres (38,849 ha)

Other Information

Project contacts:

- Mark Hurley (mark.hurley@idfg.idaho.gov), Wildlife Research Supervisor, Idaho Department of Fish and Game
- Scott Bergen (scott.bergen@idfg.idaho.gov), Senior Wildlife Research Biologist, Idaho Department of Fish and Game

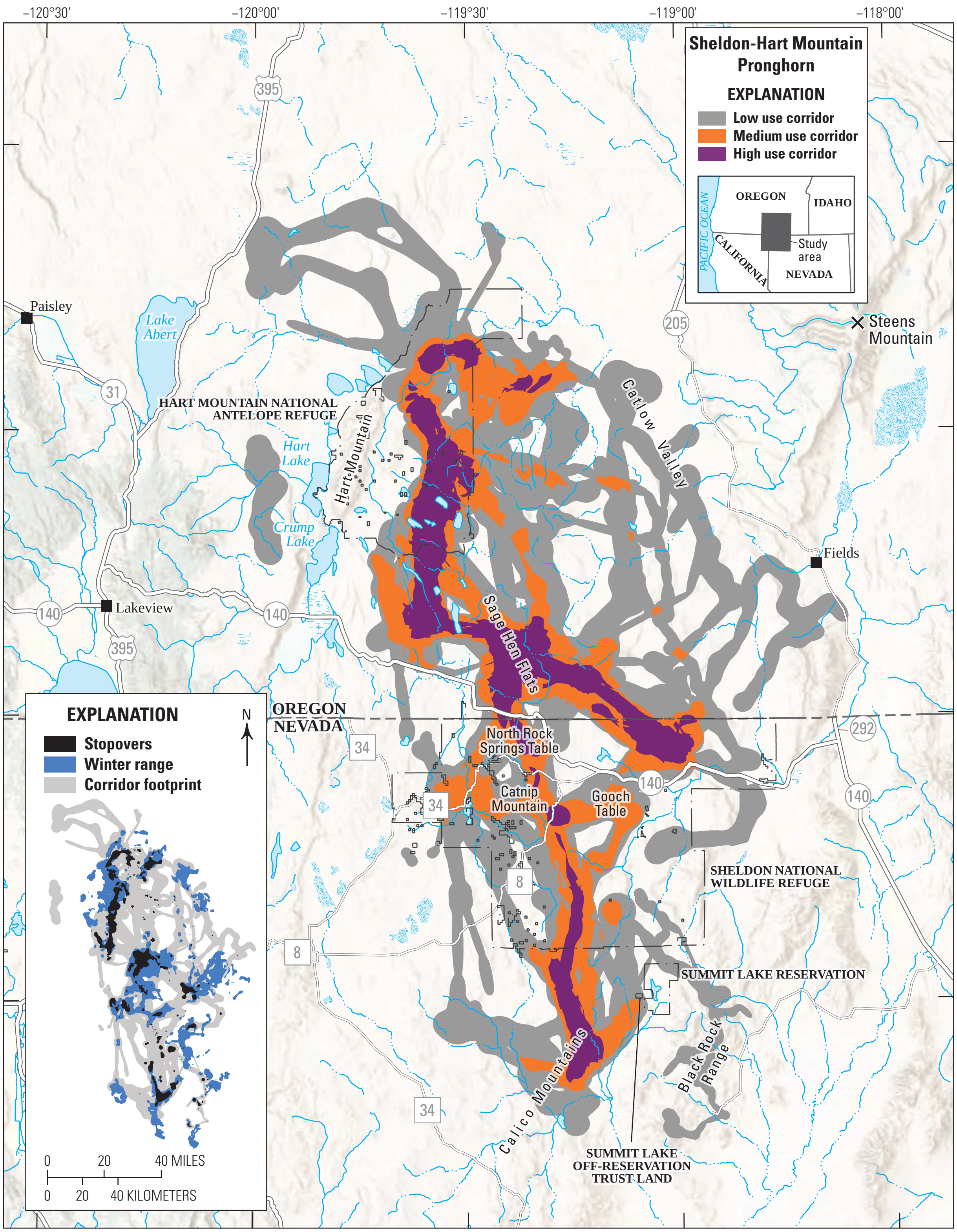
Data analyst:

- Scott Bergen, Senior Wildlife Research Biologist, Idaho Department of Fish and Game

Reports and publications:

- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game, 49 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/ID%20F16AF00908%20Statewide%20Wildlife%20Research%20Report%20FY18.pdf.]

Photograph from Scott Bergen, Idaho Department of Fish and Game.



Base from ESRI and U.S. Geological Survey digital data, 2019
Universal Transverse Mercator projection, zone 11 N
North American Datum of 1983

Figure 39. Migration corridors, stopovers, and winter ranges of the Sheldon-Hart Mountain Interstate pronghorn herd.

Nevada | Pronghorn

Sheldon-Hart Mountain Pronghorn

The Sheldon-Hart Mountain pronghorn herd is part of a large interstate metapopulation distributed across northwest Nevada, southeast Oregon, and portions of northeast California (fig. 39). Some animals travel up to 100 miles between summer and winter ranges and traverse multiple Federal land jurisdictions, including the Sheldon National Wildlife Refuge, Hart Mountain National Antelope Refuge, and surrounding BLM lands. The herd can be characterized as conditionally or partially migratory with approximately 65 percent of collared animals exhibiting migratory tendencies. Major summer ranges include portions of the Hart Mountain National Antelope Refuge, Sheldon National Wildlife Refuge, and northern Black Rock Range in Nevada. Winter ranges are distributed across Hart Mountain and east to Catlow Valley, Sage Hen Flats in Oregon and portions of the Sheldon National Wildlife Refuge including Catnip Mountain, Gooch Table, North Rock Springs Table, Summit Lake Indian Reservation, and northern Calico Mountains. Challenges to this herd include invasive annual grasses and loss of native shrubs and grasslands, depletion of limited water resources because of severe droughts, and livestock fencing prohibiting efficient movements across the landscape.

Animal Capture and Data Collection

Sample size: 32 adult female pronghorn
Relocation frequency: approximately 5.5 hours
Project duration: 2011–2013

Data Analysis

Annual range analysis: Brownian bridge movement models (Horne and others, 2007)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 79 sequences from 30 individuals (36 spring sequences, 43 fall sequences)
- Winter: 58 sequences from 31 individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: March 20 to April 10
- Fall: November 7 to November 21

Days migrating (mean):

- Spring: 17 days
- Fall: 15 days

Migration corridor length:

- Minimum: 16.5 mi (26.6 km)
- Mean: 51.1 mi (82.2 km)
- Maximum: 192.1 mi (309.2 km)

Migration corridor area:

- 3,463,106 acres (1,401,500 ha) (high use)
- 825,240 acres (333,962 ha) (medium use)
- 231,088 acres (93,518 ha) (high use)
- Stopover area: 181,940 acres (73,629 ha)

Winter Range Summary

Start and end dates (median):

- December 14 to February 1
- Days of winter use (mean): 54 days
- Winter range (50 percent contour) area: 659,806 acres (267,014 ha)

Other Information

Project contacts:

- Cody Schroeder (cschroeder@ndow.org), Wildlife Staff Specialist, Nevada Department of Wildlife
- John Tull (john_tull@fws.gov), Nevada Science Coordinator, U.S. Fish and Wildlife Service
- Don Whittaker (Don.Whittaker@state.or.us), Big Game Coordinator, Oregon Department of Wildlife

Data analyst:

- Julien Fattebert, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming

Reports and publications:

- Collins, G.H., 2016, Seasonal distribution and routes of pronghorn in the northern Great Basin, Western North American Naturalist 76 v. 1, p. 101–112.

Photograph from Tim Torell, Digital Wildlife Images.

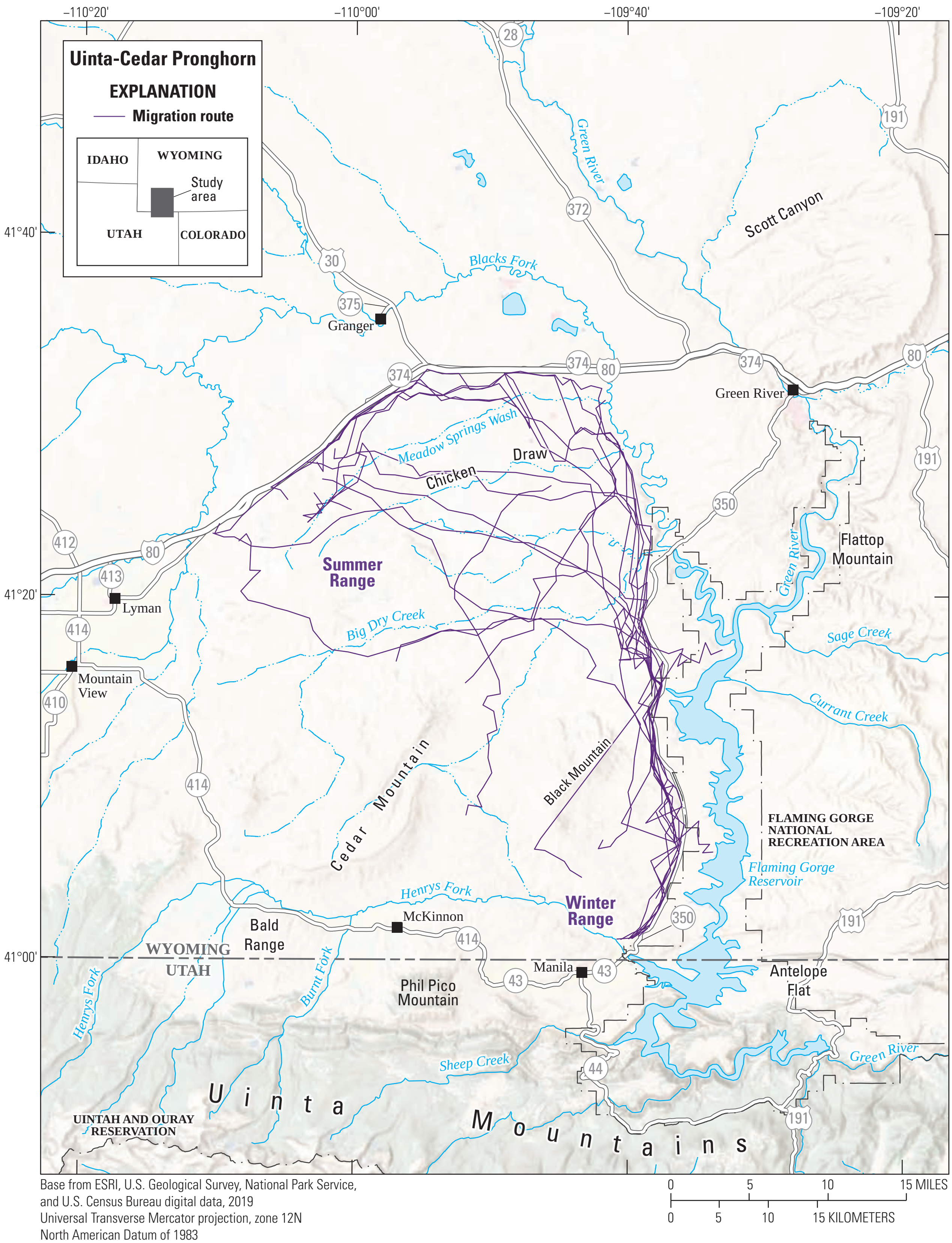


Figure 40. Migration routes of the Uinta-Cedar pronghorn herd.

Wyoming | Pronghorn

Uinta-Cedar Pronghorn

The Uinta-Cedar pronghorn herd study was tailored toward the Wyoming section of Interstate 80, and migrations and habitat use are more representative of pronghorn along Interstate 80 rather than the entire population. The Uinta-Cedar populations had the highest prevalence of seasonal migrations. This area primarily occupies checkerboard ownership between BLM and private ownership. Oil and gas drilling, as well as sheep ranching, are relatively common. Seasonal ranges are characterized by arid to semiarid habitats with *Artemisia* spp. (sagebrush) as the predominant vegetation type. Seasonal ranges can also include interspersed grasslands, and low-lying areas can also include *Sarcobatus vermiculatus* (black greasewood) and *Artiplex gardneri* (Gardner's saltbush). In the Uinta-Cedar population, south of Interstate 80, pronghorn most often had winter ranges either along Interstate 80 or to the south closer to Manila, Utah (fig. 40). The migration route pronghorn followed to access the southern winter range tended to parallel Interstate 80 in the eastern direction, then paralleled State Highway 530 and the Flaming Gorge Reservoir in the southern direction. The spring migrations were direct north movements and either paralleled State Highway 530 or were between Cedar Mountain and Black Mountain. Summer ranges were often located along Interstate 80, either to the east of Lyman or near the Blacks Fork, north of the confluence with the Green River. On average, pronghorn migrated 45.5 mi (73.3 km), with a minimum distance of 26.0 mi (41.8 km), and a maximum distance of 72.0 mi (115.9 km).

Animal Capture and Data Collection

Sample size: 9 adult female pronghorn

Relocation frequency: 1–2 hours (Telonics 1 hour, Lotek 2 hours)

Project duration: March 2017–March 2020

Data Analysis

Annual range analysis: Brownian bridge movement models (Horne and others, 2007)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 16 unique migrations from 9 individuals (5 spring migrations, 11 fall migrations)

Route Summary

Migration start and end dates (median):

- Spring: April 22 to May 7
- Fall: November 28 to January 11

Days migrating (mean):

- Spring: 11.6 days
- Fall: 18.8 days

Migration route length:

- Minimum: 26.0 mi (41.8 km)
- Mean: 45.5 mi (73.3 km)
- Maximum: 72.0 mi (115.9 km)

Other Information

Project contacts:

- Benjamin Robb (benjaminsrobb@gmail.com), Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming

Data analyst:

- Benjamin Robb, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming

Reports and publications:

- Robb, B.S., 2020, Pronghorn migrations and barriers—Predicting corridors across Wyoming's Interstate 80 to restore movement: Laramie, University of Wyoming, master's of science thesis, 78 p.

Photograph from Mark Gocke, Wyoming Game and Fish Department.

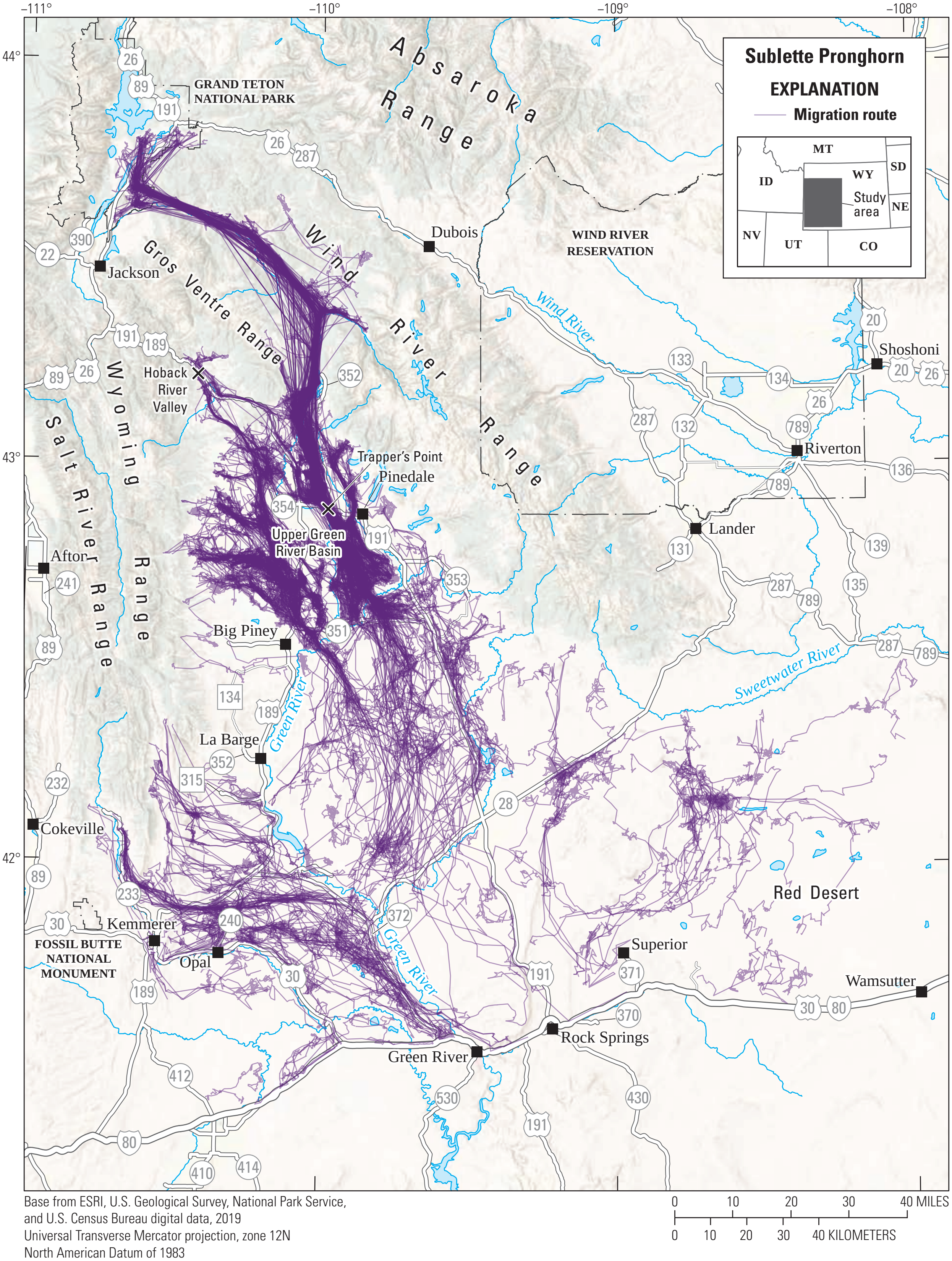


Figure 41. Migration routes of the Sublette pronghorn herd.

Wyoming | Pronghorn

Sublette Pronghorn

Pronghorn within the Sublette pronghorn herd comprise one of the largest populations in North America. Sublette pronghorn winter in the more southern areas of the upper Green River Basin of Wyoming. Depending on winter severity, individual pronghorn winter between Pinedale in the north to Rock Springs in the south, and in the western portions of the Red Desert. Winter ranges include a mix of grassland and sagebrush-dominated mesas and rolling hills. During migration, animals tracked with GPS collars (362 females) travel an average one-way distance of nearly 60 miles (96 km), with some animals migrating more than 200 miles (320 km). This herd includes the longest distance migrating pronghorn and follows the Path of the Pronghorn, the first federally designated migration corridor (fig. 41). The herd, which is estimated at 35,000 individuals, has a variety of summer range destinations. Some individuals migrate north to Grand Teton National Park following the Path of the Pronghorn. Others migrate to summer ranges in the Hoback River Valley, the Gros Ventre Range, and along the base of the Wyoming Range. Animals in the southeastern portion of the herd's range migrate in a more convoluted manner, crisscrossing the Red Desert along their migration routes. Summer ranges generally consist of higher elevation grasslands and open sagebrush habitats intermixed with mesic meadows. Sublette pronghorn have mixed movement strategies, with 55 percent of individuals displaying migratory behavior with distinct summer and winter ranges, 32 percent are nomadic with no distinct patterns between seasonal ranges, and 12 percent are resident all year in more local areas. The management population objective for this herd is 48,000 individuals, and during the early 2000s, modeled population size has oscillated between 31,000 and 62,000. Many individuals within this herd migrate or winter near energy development, mainly oil and gas development in the Pinedale Anticline, Jonah, and Calpet fields. Previous research shows pronghorn spend less time in areas after development, and in some cases, pronghorn abandon traditional winter ranges altogether. Additional gas wells are permitted in the Normally Pressurized Lance field in the center of the Sublette pronghorn herd range, and pressures are increasing from renewable energy sources such as wind and solar developments along the Interstate 80 corridor in the southern reaches of the herd. However, migrations of Sublette pronghorn benefitted from wildlife overpasses recently built over U.S. Highway 191 at the Trapper's Point and Boroff Hill sites in high-use portions of the migration route, and new crossing structures are planned to be built along U.S. Highway 189 south of Big Piney.

Animal Capture and Data Collection

Sample size: 362 adult female pronghorn
Relocation frequency: 2–5 hours
Project duration: 2002–2020

Data Analysis

Annual range analysis: Brownian bridge movement models (Horne and others, 2007)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 688 sequences from 362 individuals (409 spring sequences, 279 fall sequences)

Route Summary

Migration start and end dates (median):

- Spring: March 24 to May 4
- Fall: October 14 to October 30

Days migrating (mean):

- Spring: 42 days
- Fall: 24 days

Migration route length:

- Minimum: 9.6 mi (15.4 km)
- Mean: 59.6 mi (95.9 km)
- Maximum: 222.8 mi (358.6 km)

Other Information

Project contacts:

- Brandon Scurlock (brandon.scurlock@wyo.gov), Wyoming Game and Fish Department
- Hall Sawyer (hsawyer@west-inc.com), Western EcoSystems Technology, Inc.
- Jon Beckmann and Joel Berger (jberger@wcs.org), Wildlife Conservation Society
- Jeffrey Beck (jlbeck@uwyo.edu), University of Wyoming
- Matthew Kauffman (mkauffm1@uwyo.edu), U.S. Geological Survey, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming
- Sarah Dewey (sarah_dewey@nps.gov), Grand Teton National Park

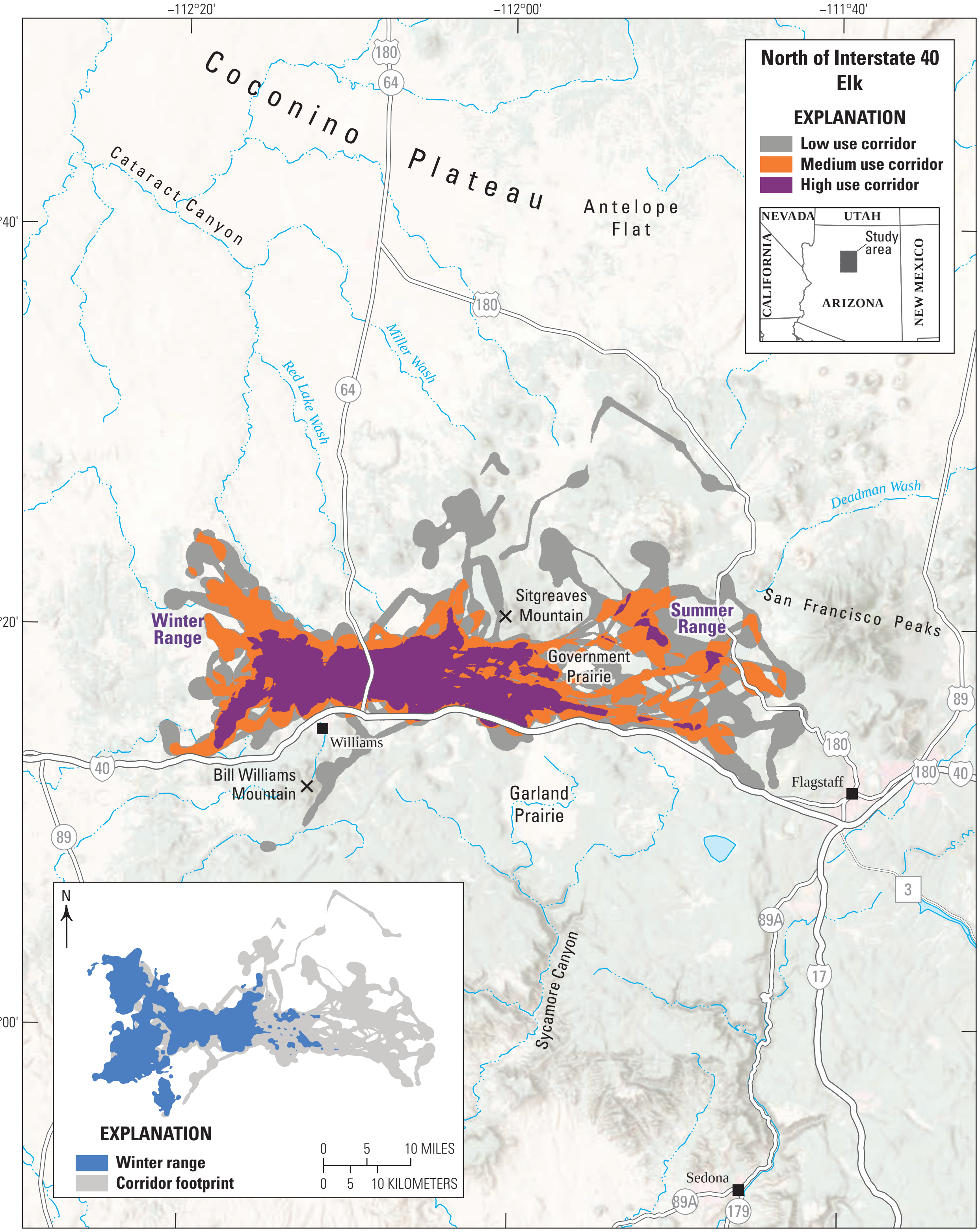
Data analyst:

- Jerod Merkle, University of Wyoming

Reports and publications:

- Beckmann, J.P., Murray, K., Seidler, R.G., and Berger, J., 2012, Human-mediated shifts in animal habitat use—Sequential changes in pronghorn use of a natural gas field in Greater Yellowstone: Biological Conservation, v. 147, no. 1, p. 222–233.
- Reinking, A.K., Smith, K.T., Mong, T.W., Read, M.J., and Beck, J.L., 2019, Across scales, pronghorn select sagebrush, avoid fences, and show negative responses to anthropogenic features in winter. Ecosphere v. 10, no. 5, p. e02722.
- Reinking, A. K., Smith, K.T., Monteith, K.L., Mong, T.W., Read, M.J., and Beck, J.L., 2018, Intrinsic, environmental, and anthropogenic factors related to pronghorn summer mortality: Journal of Wildlife Management v. 82, p. 608–617.
- Sawyer, H., Beckmann, J.P., Seidler, R.G., and Berger, J., 2019, Long-term effects of energy development on winter distribution and residency of pronghorn in the Greater Yellowstone Ecosystem: Conservation Science and Practice, v. 1, no. 9, 83 p.
- Sawyer, H., Lindzey, F., and McWhirter, D., 2005, Mule deer and pronghorn migration in western Wyoming: Wildlife Society Bulletin, v. 33, no. 4, p. 1266–1273.

Photograph from Mark Gocke, Wyoming Game and Fish Department.



Base from ESRI and U.S. Geological Survey digital data, 2019
Universal Transverse Mercator projection, zone 12N
North American Datum of 1983

Figure 42. Migration corridors and winter ranges of the north of Interstate 40 elk herd.

Arizona | Elk

North of Interstate 40 Elk

The North of Interstate 40 elk herd migrates through some of Arizona's high elevation landscapes west of Flagstaff (fig. 42). The bulk of the herd resides in Arizona's GMU 7W during the summer, and during the winter many migrate to GMU 10. The GMU 7W population had an estimate of 4,300 individuals in 2019, while the GMU 10 population had an estimate of 3,200. Like many elk in Arizona, only a portion of the herd is migratory. Summer range contains ponderosa pine forests and open prairies near Government Prairie and Sitgreaves Mountain. In the winter, the elk transition to gradually lower elevations and habitats dominated by pinyon-juniper woodlands. Interstate 40 and State Route 64 are primary threats to this migration corridor. Successful elk crossings of Interstate 40 are rare, and research has shown there are more than 65 elk-vehicle collisions per year along this stretch (Gagnon and others, 2012).

Animal Capture and Data Collection

Sample size: 18 adult elk (4 male, 14 female)
Relocation frequency: approximately 2 hours, 8 fixes per day
Project duration: 2009–2011

Data Analysis

Corridor, stopover, and winter range analysis: Brownian bridge movement models (Sawyer and others, 2009); corridor analysis used Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 49 sequences from 18 individuals (23 spring sequences, 26 fall sequences)
- Winter: 28 sequences from 18 individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: April 9 to April 19
- Fall: December 7 to December 22

Average number of days migrating:

- Spring: 13 days
- Fall: 17 days

Migration corridor length:

- Minimum: 11 mi (18 km)
- Mean: 29 mi (47 km)
- Maximum: 62 mi (100 km)

Migration corridor area:

- 174,008 acres (70,419 ha) (low use)
- 94,046 acres (38,059 ha) (medium use)
- 44,799 acres (18,130 ha) (high use)

Winter Range Summary

Winter start and end dates (median):

- December 22 to April 9
- Winter length (mean): 109 days
- Winter range (50 percent contour) area: 111,936 acres (45,300 ha)

Other Information

Project contacts:

- Jeff Gagnon (jgagnon@azgfd.gov), Wildlife Specialist Regional Supervisor, Arizona Game and Fish Department
- Scott Sprague (ssprague@azgfd.gov), Project Manager/Road Ecologist, Arizona Game and Fish Department

Data analyst:

- Lucas Olson, Cooperative Mule Deer Biologist, Mule Deer Foundation and Arizona Game and Fish Department

Reports and publications:

- Dodd, N.L., Gagnon, J.W., Sprague, S.C., Boe, S., and Schweinsburg, R.E., 2012, Wildlife accident reduction study and monitoring—Arizona State Route 64: Phoenix, Ariz., Arizona Department of Transportation Research Center, Final project report 626, 118 p. [Also available at https://arc-solutions.org/wp-content/uploads/2013/02/AZ626-Wildlife-Accident-Reduction-Study-Monitoring-Az-State-Route-64.pdf.]
- Gagnon, J.W., Sprague, S.C., Dodd, N.L., Nelson, R.E., III, Boe, S.R., and Schweinsburg, R.E., 2012, Research report prepared by Arizona Game and Fish Department on elk movements associated with Interstate 40 (Williams to Winona) for Design Concept Study and Environmental Assessment Interstate 40 Bellemont to Winona Project No. NH 040-C(211)S 40 CN 183 H758601L: Arizona Game and Fish Department, 86 p.

Photograph from George Andrejko, Arizona Game and Fish Department.

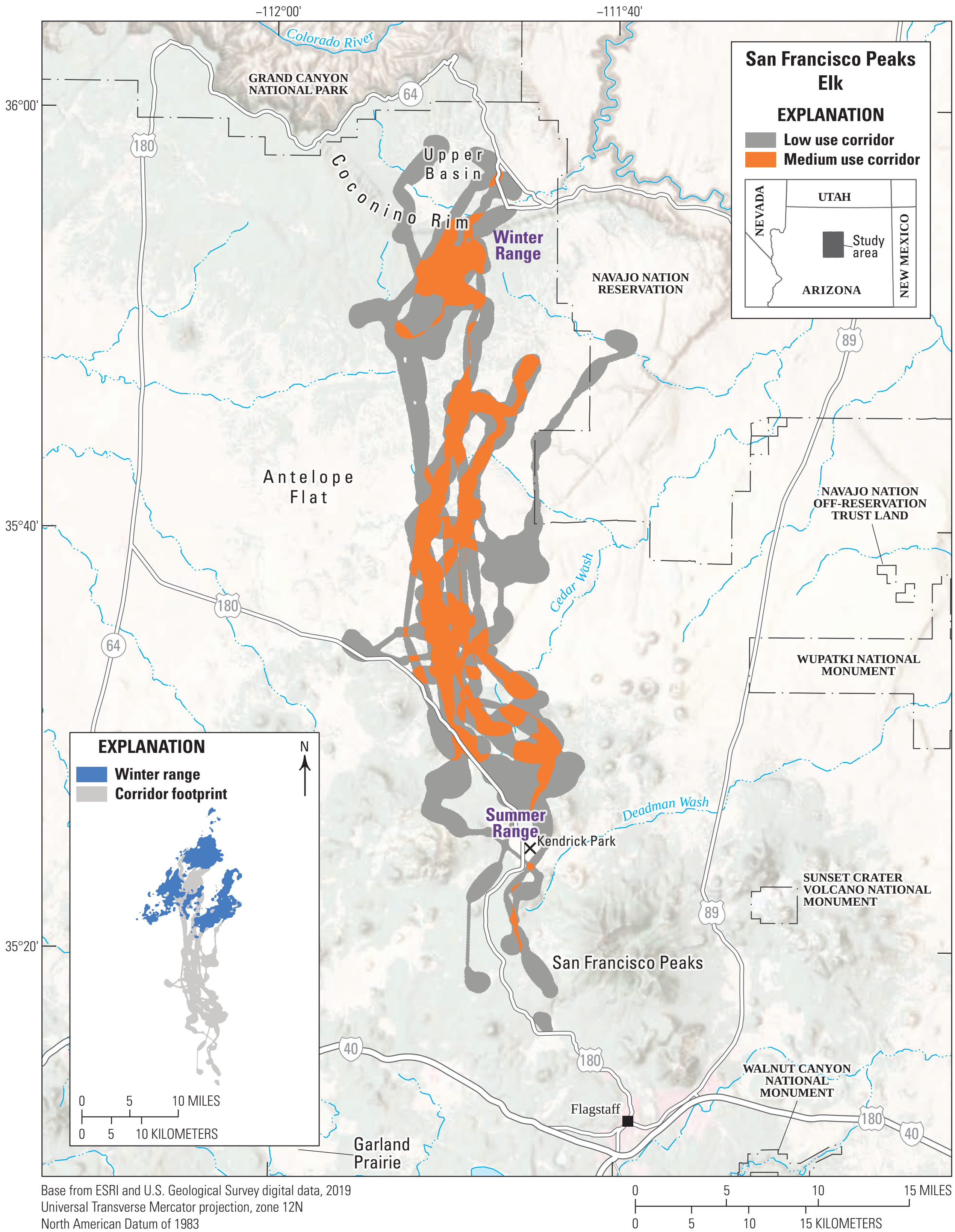


Figure 43. Migration corridors and winter ranges of the San Francisco Peaks elk herd.

Arizona | Elk

San Francisco Peaks Elk

The San Francisco Peaks elk herd comprises a migratory portion of the larger herd units in Arizona's GMU 7 and 9 (figs. 43). GMU 7 and 9 had a combined population estimate of 5,200 in 2019. These data were generated from two elk research projects by the Arizona Game and Fish Department: one to assess elk-vehicle collisions on Interstate 40 (Gagnon and others, 2012) and the other to evaluate aerial survey methods for elk abundance (Bristow and others, 2019). While many of the elk reside in the same general areas year round, the migratory portion of this herd migrates an average of 42 miles between summer and winter range. Summer range, primarily in GMU 7, consists of high elevation open meadows and ponderosa pine forests around the San Francisco Peaks and Kendrick Park. Winter range contains a mix of ponderosa pine, pinyon juniper, and sagebrush habitats along the Coconino Rim and Upper Basin. Obstacles to migration for this herd are predominantly roads including State Route 64 and U.S. Highway 180.

Animal Capture and Data Collection

Sample size: 6 adult elk (1 male, 5 female)
Relocation frequency: approximately 3–7 hours
Project duration: 2009–2011; 2015–2017

Data Analysis

Corridor, stopover, and winter range analysis: Brownian bridge movement models (Sawyer and others, 2009); corridor analysis used Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 11 sequences from 6 individuals (5 spring sequences, 6 fall sequences)
- Winter: 6 sequences from 6 individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: March 28 to April 8
- Fall: December 3 to December 16

Average number of days migrating:

- Spring: 10 days
- Fall: 13 days

Migration corridor length:

- Minimum: 17 mi (27 km)
- Mean: 42 mi (68 km)
- Maximum: 69 mi (111 km)

Migration corridor area:

- 132,396 acres (53,579 ha) (low use)
- 43,663 acres (17,670 ha) (medium use)

Winter Range Summary

Winter start and end dates (median):

- December 16 to March 28
- Winter length (mean): 98 days
- Winter range (50 percent contour) area: 88,215 acres (35,699 ha)

Other Information

Project contacts:

- Jeff Gagnon (jgagnon@azgfd.gov), Wildlife Specialist Regional Supervisor, Arizona Game and Fish Department
- Scott Sprague (ssprague@azgfd.gov), Project Manager and Road Ecologist, Arizona Game and Fish Department

Data analyst:

- Lucas Olson, Cooperative Mule Deer Biologist, Mule Deer Foundation and Arizona Game and Fish Department

Reports and publications:

- Bristow, K.D., Clement, M.J., Crabb, M.L., Harding, L.E., and Rubin, E.S., 2019, Comparison of aerial survey methods for elk in Arizona: Wildlife Society Bulletin, v. 43, no. 1, p. 77–92, https://doi.org/10.1002/wsb.940.
- Gagnon, J.W., Sprague, S.C., Dodd, N.L., Nelson, R.E., III, Boe, S.E., and Schweinsburg, R.E., 2012, Research report prepared by Arizona Game and Fish Department on elk movements associated with Interstate 40 (Williams to Winona) for Design Concept Study and Environmental Assessment Interstate 40 Bellemont to Winona Project No. NH 040-C(211)S 40 CN 183 H758601L: Arizona Game and Fish Department, 86 p.

Photograph from George Andrejko, Arizona Game and Fish Department.

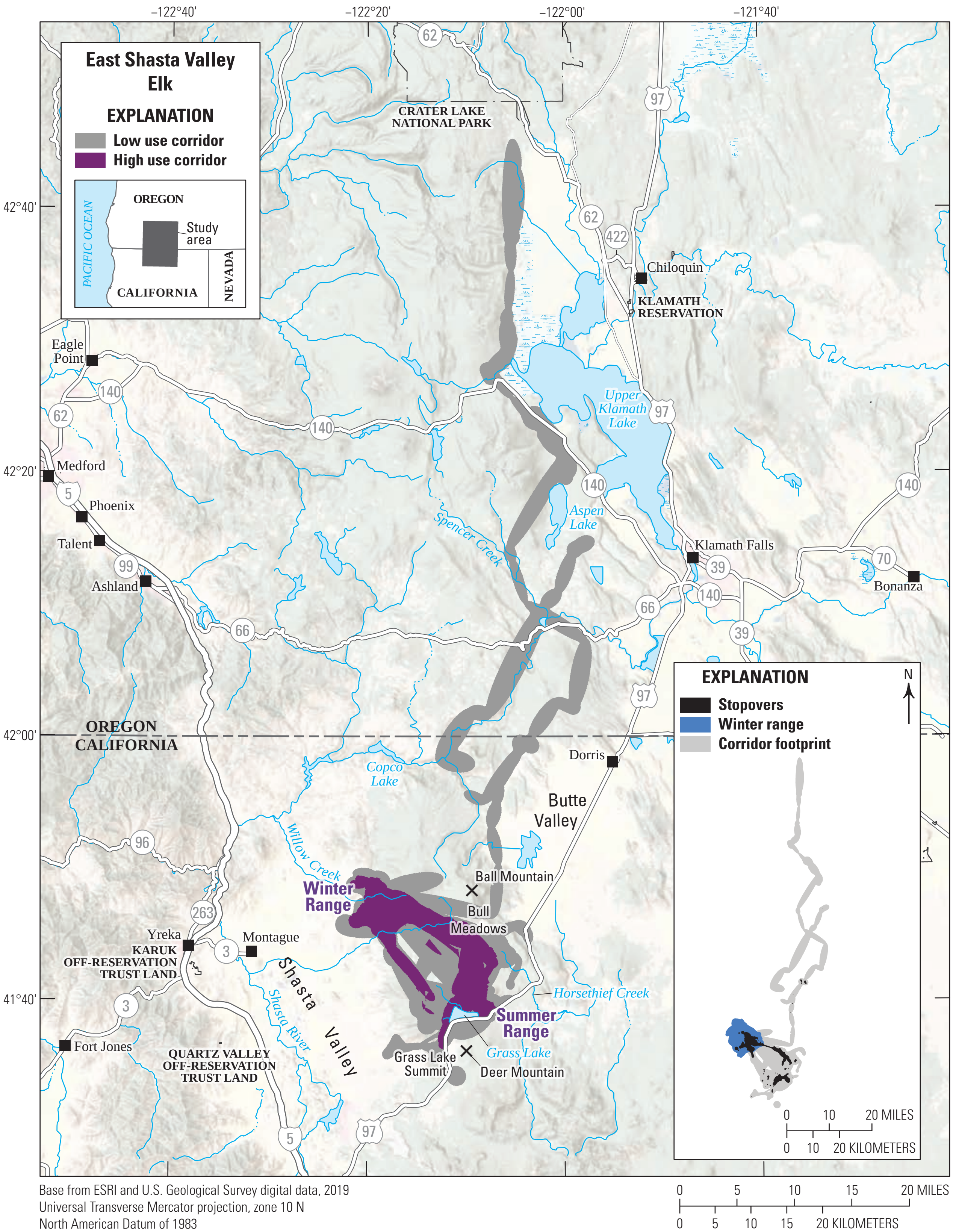


Figure 44. Migration corridors, stopovers, and winter ranges of the East Shasta Valley elk herd.

California | Elk

East Shasta Valley Elk

The East Shasta Valley elk subherd spend most of their time on private ranchlands in Shasta Valley in California in the winter. This area offers patches of oak woodlands and grasslands on gentle slopes. In the spring, elk migrate to their summer range around Grass Lake, Bull Meadow, and Deer Mountain where the habitat is primarily characterized by mixed conifer timber stands of *Pinus ponderosa* (ponderosa pine), *Pinus contorta* (lodgepole pine) and *Pseudotsuga menziesii* (Douglas fir; fig. 44). The meadows around Grass Lake seem especially important to this subherd, as neonatal calves have been documented in this area since at least 1984 (Fischer, 1987). Some animals from this subherd migrate into Oregon or move eastward to other subherds, but U.S. Highway 97 presents a significant barrier to this movement, with many documented vehicle collisions between Horsethief Creek and Grass Lake Summit. A wildlife crossing is proposed for this area to promote habitat connectivity and wildlife movement.

Animal Capture and Data Collection

Sample size: 12 adult females, 1 adult male, 8 juvenile females, and 5 juvenile males

Relocation frequency: 3–8 hours

Project duration: 1999–2001; 2016–2020

Data Analysis

Corridor, stopover, and winter range analysis: Brownian bridge movement models (Sawyer and others, 2009); corridor analysis used Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 59 sequences from 18 individuals (32 spring sequences, 27 fall sequences)
- Winter: 27 sequences from 14 individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: March 21 to March 23
- Fall: July 27 to July 31

Average number of days migrating:

- Spring: 6 days
- Fall: 4 days

Migration corridor length:

- Minimum: 9.64 mi (15.51 km)
- Mean: 14.82 mi (23.85 km)
- Maximum: 71.73 mi (115.44 km)

Migration corridor area:

- 185,004 acres (74,868 ha) (low use)
- 40,747 acres (16,490 ha) (high use)
- Stopover area: 19,027 acres (7,700 ha)

Winter Range Summary

Winter start and end dates (median):

- August 4 to March 21
- Winter length (mean): 109 days
- Winter range (50 percent contour) area: 111,936 acres (45,300 ha)

Other Information

Project contacts:

- Kristin Denryter (Kristin.Denryter@wildlife.ca.gov), Senior Environmental Scientist, California Department of Fish and Wildlife
- Erin Zulliger (Erin.Zulliger@Wildlife.ca.gov), Elk Biologist, California Department of Fish and Wildlife
- Michael (Axel) Hunnicutt (Michael.hunnicutt@wildlife.ca.gov), Environmental Scientist, California Department of Fish and Wildlife
- Christine Found-Jackson (Christine.Found-Jackson@wildlife.ca.gov), Wildlife Biologist, California Department of Fish and Wildlife

Data analyst:

- Evan Greenspan, Senior GIS Analyst, California Department of Fish and Wildlife

Reports and publications:

- Fisher, J.K., 1987, Elk habitat use and group size in the Grass Lake area of Siskiyou county, California: Arcata, California, Humbolt State University, master's thesis, 76 p.

Photograph from Erin Zullinger, California Department of Fish and Wildlife.

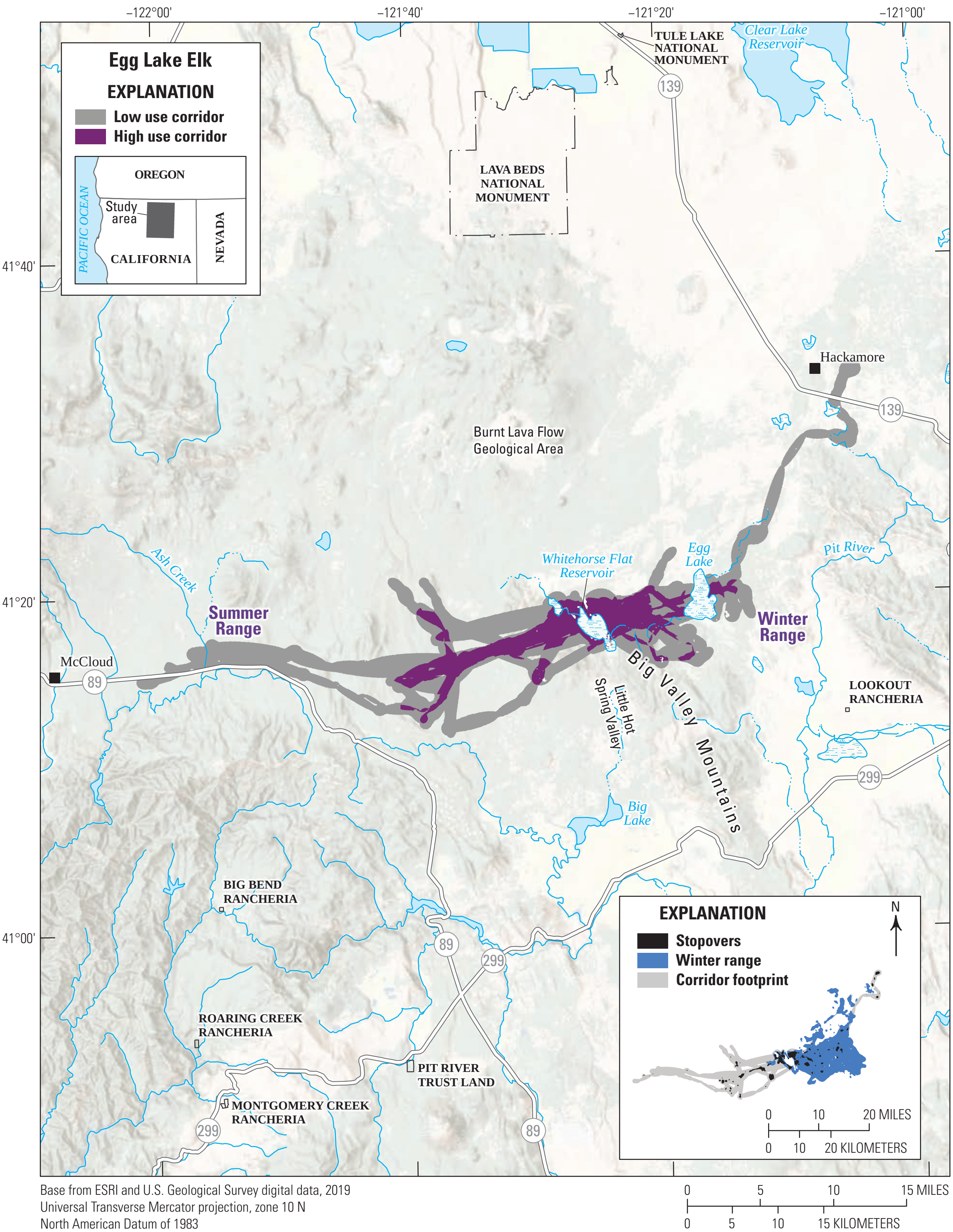


Figure 45. Migration corridors, stopovers, and winter ranges of the Egg Lake elk subherd.

California | Elk

Egg Lake Elk

The Egg Lake elk subherd range extends northeast from McCloud, California around Ash Creek to the Big Valley Mountains and as far east as State Route 139 near Hackamore (fig. 45). During the winter, this subherd primarily resides to the east of Big Valley Mountains near Egg Lake in Modoc County, California. They migrate east to private timberlands and spend the spring and summer just outside of McCloud, California. Topography of this area is relatively flat, but gradually transitions to steeper slopes around creeks, and typical habitat includes ponderosa pine, mixed conifer, and montane hardwood conifer forests. Another subherd is known to exist on the east side of State Route 139 near Clear Lake Reservoir, California and may present a barrier between the two subherds as some mortality has been documented on the highway, but the full extent of this is unknown.

Animal Capture and Data Collection

Sample size: 12 adult females, 3 juvenile males, and 2 juvenile females

Relocation frequency: 3–8 hours

Project duration: 2001–2002; 2017–2020

Data Analysis

Corridor, stopover, and winter range analysis: Brownian bridge movement models (Sawyer and others, 2009); corridor analysis used Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 22 sequences from 11 individuals (13 spring sequences, 9 fall sequences)
- Winter: 17 sequences from 9 individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: April 20 to April 29
- Fall: November 19 to November 28

Average number of days migrating:

- Spring: 8 days
- Fall: 7 days

Migration corridor length:

- Minimum: 12.20 mi (19.63 km)
- Mean: 22.56 mi (36.31 km)
- Maximum: 38.71 mi (62.30 km)

Migration corridor area:

- 105,265 acres (42,599 ha) (low use)
- 28,762 acres (11,640 ha) (high use)
- Stopover area: 10,650 acres (4,310 ha)

Winter Range Summary

Winter start and end dates (median):

- December 2 to April 21
- Winter length (mean): 140 days
- Winter range (50 percent contour) area: 126,540 acres (51,209 ha)

Other Information

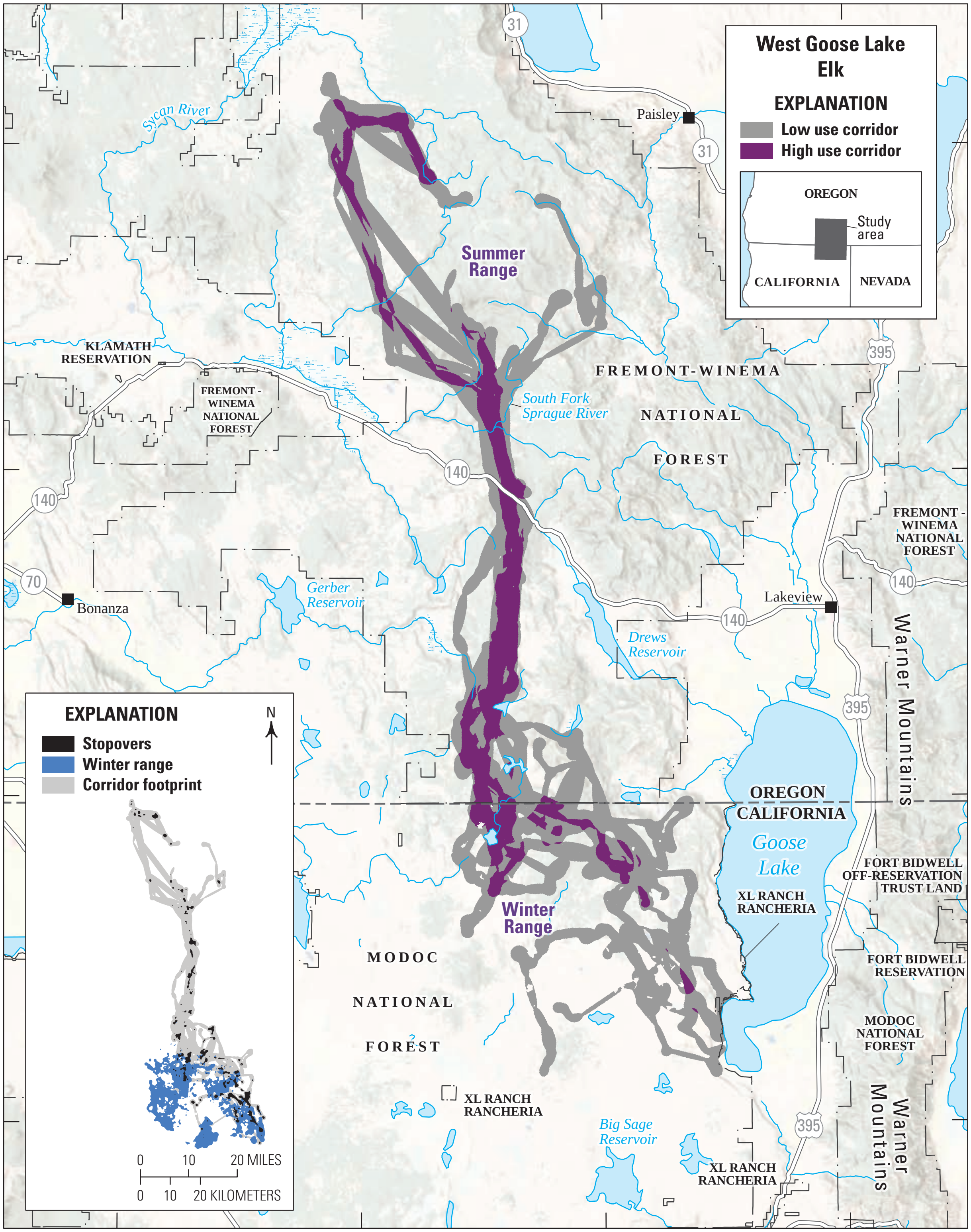
Project contacts:

- Kristin Denryter (Kristin.Denryter@wildlife.ca.gov), Senior Environmental Scientist, California Department of Fish and Wildlife
- Erin Zulliger (Erin.Zulliger@Wildlife.ca.gov), Elk Biologist, California Department of Fish and Wildlife
- Richard Shinn (Richard.shinn@wildlife.ca.gov), Environmental Scientist, California Department of Fish and Wildlife
- Christine Found-Jackson (Christine.Found-Jackson@wildlife.ca.gov), Wildlife Biologist, California Department of Fish and Wildlife

Data analyst:

- Evan Greenspan, Senior GIS Analyst, California Department of Fish and Wildlife

Photograph from Rocky Mountain Elk Foundation.



Base from ESRI and U.S. Geological Survey digital data, 2019
Universal Transverse Mercator projection, zone 11 N
North American Datum of 1983

0 5 10 15 MILES
0 5 10 15 KILOMETERS

Figure 46. Migration corridors, stopovers, and winter ranges of the West Goose Lake elk subherd.

California | Elk

West Goose Lake Elk

The winter range of the West Goose Lake elk subherd is located north of Alturas and west of U.S. Highway 395 within the Modoc National Forest in California (fig. 46). This area is characterized by *Juniperus occidentalis* (western juniper) woodlands, and sagebrush flats with some stands of lodgepole pine and ponderosa pine throughout flat, rocky terrain. From this area, a portion of the herd migrates approximately 50 miles north into Fremont-Winema National Forest in Oregon, habitat primarily consists of lodgepole and ponderosa pine forests. Minimal barriers exist along this migration route because the corridor primarily occurs on land managed by the USFS. Additionally, although the core migration route does cross State Route 140, little to no effects are known to exist from this crossing.

Animal Capture and Data Collection

Sample size: 14 adult females, 2 adult male, and 3 juvenile males

Relocation frequency: 4–8 hours

Project duration: 1999–2002; 2018–2020

Data Analysis

Corridor, stopover, and winter range analysis: Brownian bridge movement models (Sawyer and others, 2009); corridor analysis used Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 25 sequences from 12 individuals (14 spring sequences, 11 fall sequences)
- Winter: 17 sequences from 11 individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: April 14 to April 28
- Fall: October 25 to November 4

Average number of days migrating:

- Spring: 11 days
- Fall: 10 days

Migration corridor length:

- Minimum: 4.27 mi (6.87 km)
- Mean: 30.71 mi (49.42 km)
- Maximum: 56.06 mi (90.22 km)

Migration corridor area:

- 242,010 acres (97,938 ha) (low use)
- 60,787 acres (24,600 ha) (high use)
- Stopover area: 24,710 acres (10,000 ha)

Winter Range Summary

Winter start and end dates (median):

- November 5 to April 7
- Winter length (mean): 153 days
- Winter range (50 percent contour) area: 112,183 acres (45,399 ha)

Other Information

Project contacts:

- Kristin Denryter (Kristin.Denryter@wildlife.ca.gov), Senior Environmental Scientist, California Department of Fish and Wildlife
- Erin Zulliger (Erin.Zulliger@Wildlife.ca.gov), Elk Biologist, California Department of Fish and Wildlife
- Richard Shinn (Richard.shinn@wildlife.ca.gov), Environmental Scientist, California Department of Fish and Wildlife
- Christine Found-Jackson (Christine.Found-Jackson@wildlife.ca.gov), Wildlife Biologist, California Department of Fish and Wildlife

Data analyst:

- Evan Greenspan, Senior GIS Analyst, California Department of Fish and Wildlife

Photograph from Erin Zullinger, California Department of Fish and Wildlife.

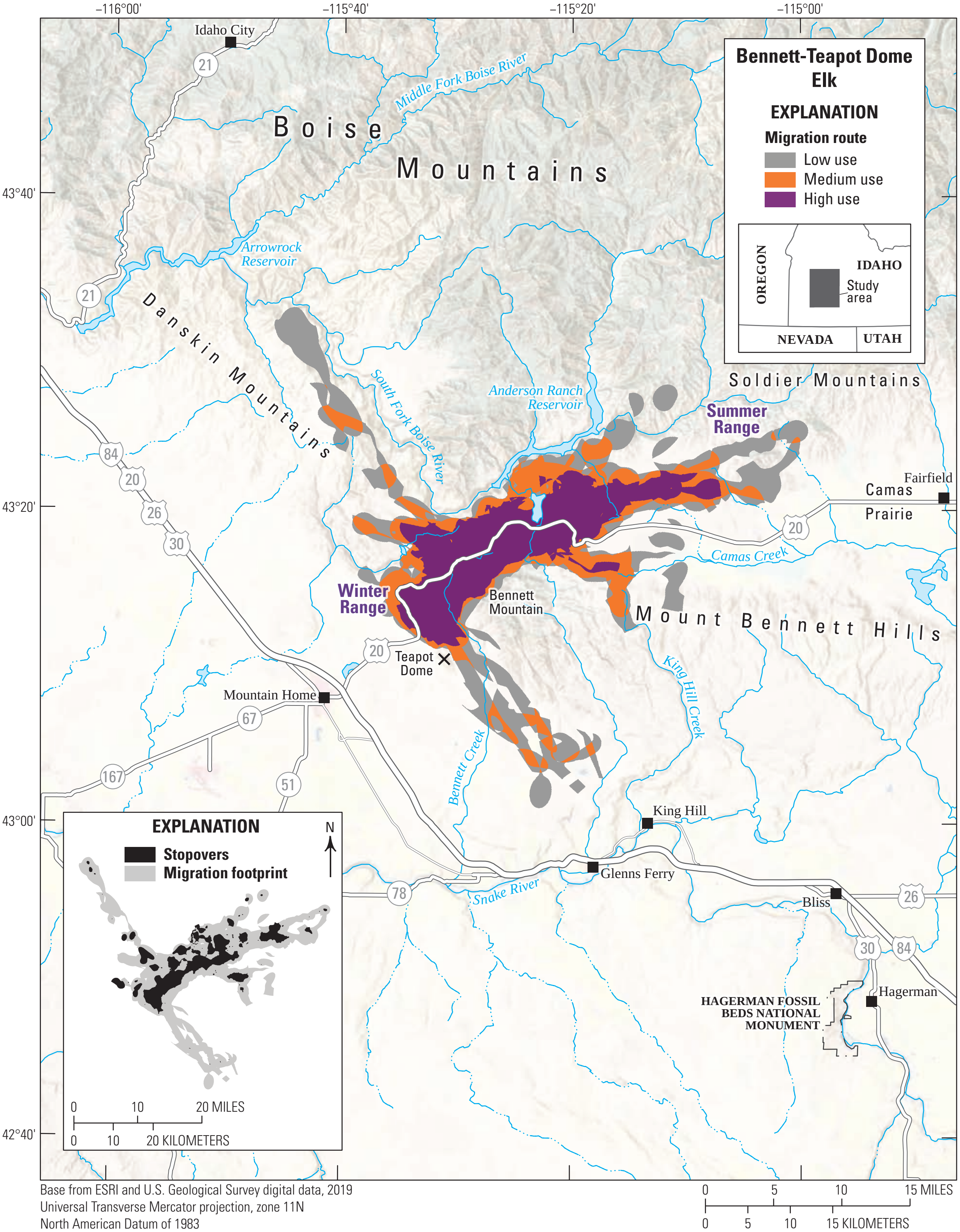


Figure 47. Migration routes and stopovers of the Bennett-Teapot Dome elk herd.

Idaho | Elk

Bennett-Teapot Dome Elk

The Bennett-Teapot Dome elk herd winters in the foothills of Bennett Mountain between Teapot Dome northeast of Mountain Home and King Hill northeast of Glenns Ferry, Idaho. Elk wintering in this area typically traverse the Bennett Mountains to reach summer ranges in the Soldier Mountains (fig. 47). On average, Bennett-Teapot Dome elk travel more than 42 miles to migrate between winter and summer ranges, with some individuals traveling more than 95 miles. These animals are part of the broader Smoky-Bennett elk population, which was estimated by aerial survey to be 3,622 elk in 2021, down from 4,874 elk counted in 2015. Wildfire and the establishment of invasive species, such as medusahead and cheatgrass, have compromised a large portion of the winter range used by this elk herd. Additionally, U.S. Highway 20, which serves as a connector route between Boise and Sun Valley, has seen increasing traffic volumes and an elevated risk of wildlife-vehicle collisions. Proposed energy development projects could also affect this elk herd, particularly during migration.

Animal Capture and Data Collection

Sample size: 25 female elk
Relocation frequency: 20 minutes–23 hours
Project duration: February 2015–December 2019

Data Analysis

Migration and stopover analysis: Brownian bridge movement models (Sawyer and others, 2009); Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 46 sequences from 25 individuals (28 spring sequences, 18 fall sequences)

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: March 15 to April 20
- Fall: October 30 to November 30

Average number of days migrating:

- Spring: 39 days
- Fall: 24 days

Migration length:

- Minimum: 12.6 mi (20.3 km)
- Mean: 41.9 mi (67.4 km)
- Maximum: 95.0 mi (152.9 km)

Migration area:

- 354,497 acres (143,460 ha) (low use; 10 percent)
- 170,994 acres (69,199 ha) (medium use; 10–20 percent)
- 63,639 acres (25,754 ha) (high use; greater than 20 percent)
- Stopover area: 48,479 acres (19,619 ha)

Other Information

Project contacts:

- Mark Hurley (mark.hurley@idfg.idaho.gov), Wildlife Research Supervisor, Idaho Department of Fish and Game
- Mike McDonald (mike.mcdonald@idfg.idaho.gov), Regional Wildlife Manager, Idaho Department of Fish and Game

Data analysts:

- Jodi Berg, Senior Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming
- Scott Bergen, Senior Wildlife Research Biologist, Idaho Department of Fish and Game

Reports and publications:

- Ellstrom, M., Hickey, C., Ward, R., Berkley, R., McDonald, M., Lockyer, Z., Hendricks, C., Painter, G., Roche, E., Elmer, M., and Smith, D., 2019, Mule deer surveys and inventories statewide report 2018 seasons: Boise, Idaho, Idaho Department of Fish and Game, 117 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/Mule%20Deer%20Statewide%20FY2019.pdf.]
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game, 49 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/ID%20F16AF00908%20Statewide%20Wildlife%20Research%20Report%20FY18.pdf.]


Photograph from Idaho Department of Fish and Game.

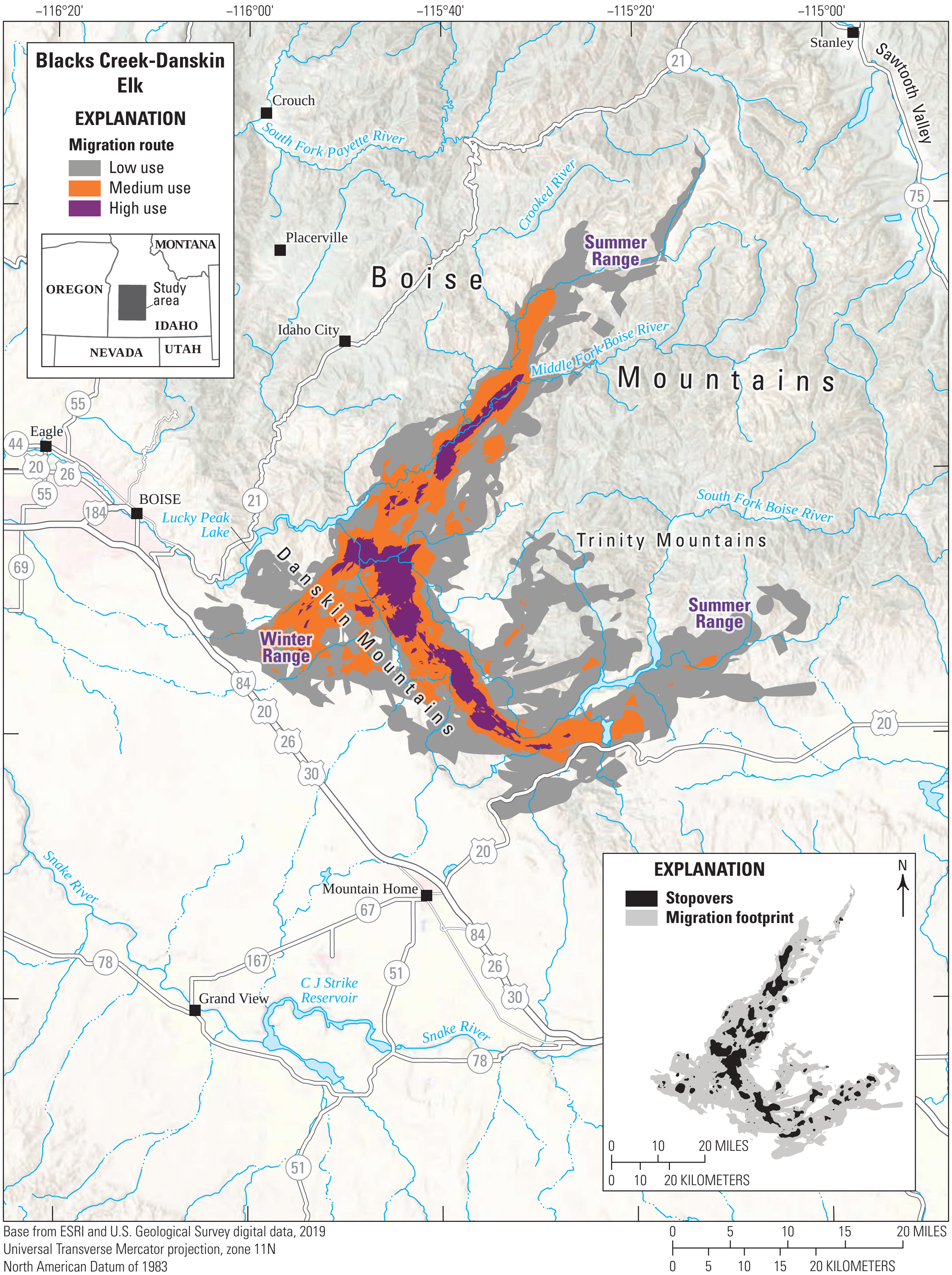


Figure 48. Migration routes and stopovers of the Blacks Creek-Danskin elk herd.

Idaho | Elk

Blacks Creek-Danskin Elk

The Blacks Creek-Danskin elk herd winters in the foothills southeast of Lucky Peak Lake in Idaho. During their spring migrations, these elk typically traverse the Middle Fork Boise River and South Fork Boise River using two main migration routes to reach summer ranges much farther up the valleys in the Boise Mountains (fig. 48). They may also travel as far as the Sawtooth Valley. On average, the Blacks Creek-Danskin elk herd travels more than 44 miles to migrate between winter and summer range. Individuals with the longest routes may travel more than 140 miles. The population in the Boise River Elk Zone was estimated to be 8,800 elk in 2021.

Animal Capture and Data Collection

Sample size: 45 female elk
Relocation frequency: 2–23 hours
Project duration: November 2009–December 2019

Data Analysis

Migration and stopover analysis: Brownian bridge movement models (Sawyer and others, 2009); Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 92 sequences from 45 individuals (55 spring sequences, 37 fall sequences)

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: April 4 to April 29
- Fall: November 2 to December 21

Average number of days migrating:

- Spring: 27 days
- Fall: 35 days

Migration length:

- Minimum: 10.5 mi (16.9 km)
- Mean: 44.6 mi (71.8 km)
- Maximum: 140.6 mi (226.3 km)

Migration area:

- 684,664 acres (227,074 ha) (low use; 10 percent)
- 195,868 acres (79,265 ha) (medium use; 10–20 percent)
- 39,057 acres (15,806 ha) (high use; greater than 20 percent)
- Stopover area: 89,127 acres (36,068 ha)

Other Information

Project contacts:

- Mark Hurley (mark.hurley@idfg.idaho.gov), Wildlife Research Supervisor, Idaho Department of Fish and Game
- Ryan Walrath (ryan.walrath@idfg.idaho.gov), Regional Wildlife Manager, Idaho Department of Fish and Game

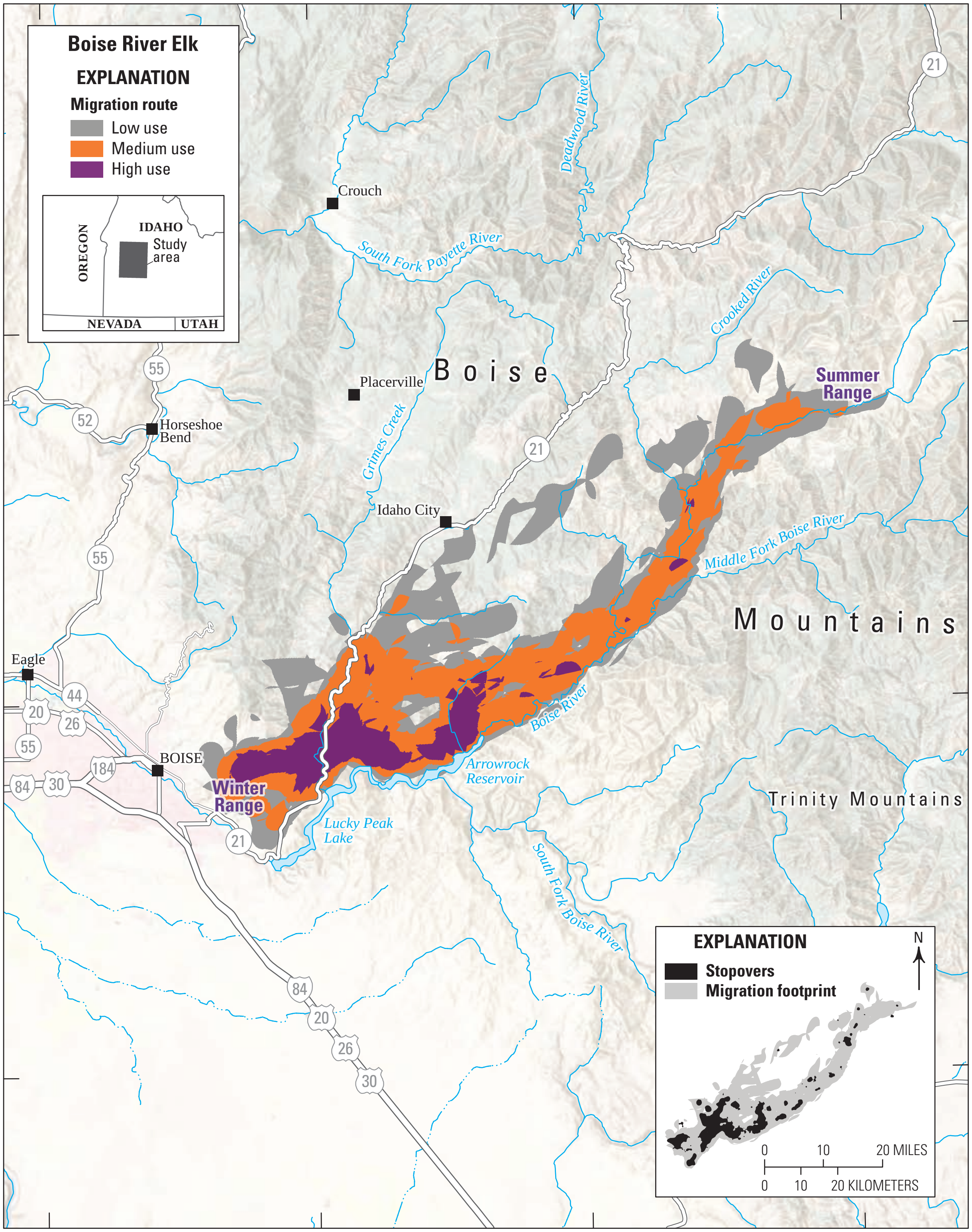
Data analysts:

- Jodi Berg, Senior Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming
- Scott Bergen, Senior Wildlife Research Biologist, Idaho Department of Fish and Game

Reports and publications:

- Ellstrom, M., Hickey, C., Ward, R., Berkley, R., McDonald, M., Lockyer, Z., Hendricks, C., Painter, G., Roche, E., Elmer, M., and Smith, D., 2019, Mule deer surveys and inventories statewide report 2018 seasons: Boise, Idaho, Idaho Department of Fish and Game, 117 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/Mule%20Deer%20Statewide%20FY2019.pdf.]
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game, 49 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/ID%20F16AF00908%20Statewide%20Wildlife%20Research%20Report%20FY18.pdf.]

Photograph from Idaho Department of Fish and Game.



Base from ESRI and U.S. Geological Survey digital data, 2019
Universal Transverse Mercator projection, zone 11N
North American Datum of 1983

0 5 10 15 MILES
0 5 10 15 KILOMETERS

Figure 49. Migration routes and stopovers of the Boise River elk herd.

Idaho | Elk

Boise River Elk

The Boise River elk herd uses areas of the foothills west of Lucky Peak Lake in Idaho in winter. Elk wintering in this area typically migrate to summer range in the upper Boise River watershed (fig. 49). On average, the Boise River elk herd travels more than 26 miles to migrate between summer and winter range, with the farthest individuals traveling more than 63 miles. Elk must navigate State Highway 21 near Lucky Peak Lake, an area where wildlife-vehicle collisions have regularly occurred. However, recent and upcoming infrastructure improvement projects are mitigating some of those issues. The population in the Boise River Elk Zone was estimated to be 8,800 elk in 2021.

Animal Capture and Data Collection

Sample size: 39 female elk
Relocation frequency: 13–23 hours
Project duration: March 2015–January 2020

Data Analysis

Migration and stopover analysis: Brownian bridge movement models (Sawyer and others, 2009); Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 71 sequences from 39 individuals (50 spring sequences, 21 fall sequences)

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: April 8 to April 26
- Fall: November 30 to December 20

Average number of days migrating:

- Spring: 23 days
- Fall: 18 days

Migration length:

- Minimum: 6.4 mi (10.3 km)
- Mean: 26.1 mi (42.0 km)
- Maximum: 63.5 mi (102.2 km)

Migration area:

- 308,944 acres (125,025 ha) (low use; 10 percent)
- 123,656 acres (50,042 ha) (medium use; 10–20 percent)
- 25,556 acres (10,342 ha) (high use; greater than 20 percent)

Other Information

Project contacts:

- Mark Hurley (mark.hurley@idfg.idaho.gov), Wildlife Research Supervisor, Idaho Department of Fish and Game
- Ryan Walrath (ryan.walrath@idfg.idaho.gov), Regional Wildlife Manager, Idaho Department of Fish and Game

Data analysts:

- Jodi Berg, Senior Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming
- Scott Bergen, Senior Wildlife Research Biologist, Idaho Department of Fish and Game

Reports and publications:

- Ellstrom, M., Hickey, C., Ward, R., Berkley, R., McDonald, M., Lockyer, Z., Hendricks, C., Painter, G., Roche, E., Elmer, M., and Smith, D., 2019, Mule deer surveys and inventories statewide report 2018 seasons: Boise, Idaho, Idaho Department of Fish and Game, 117 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/Mule%20Deer%20Statewide%20FY2019.pdf.]
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game, 49 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/ID%20F16AF00908%20Statewide%20Wildlife%20Research%20Report%20FY18.pdf.]

Photograph from Idaho Department of Fish and Game.

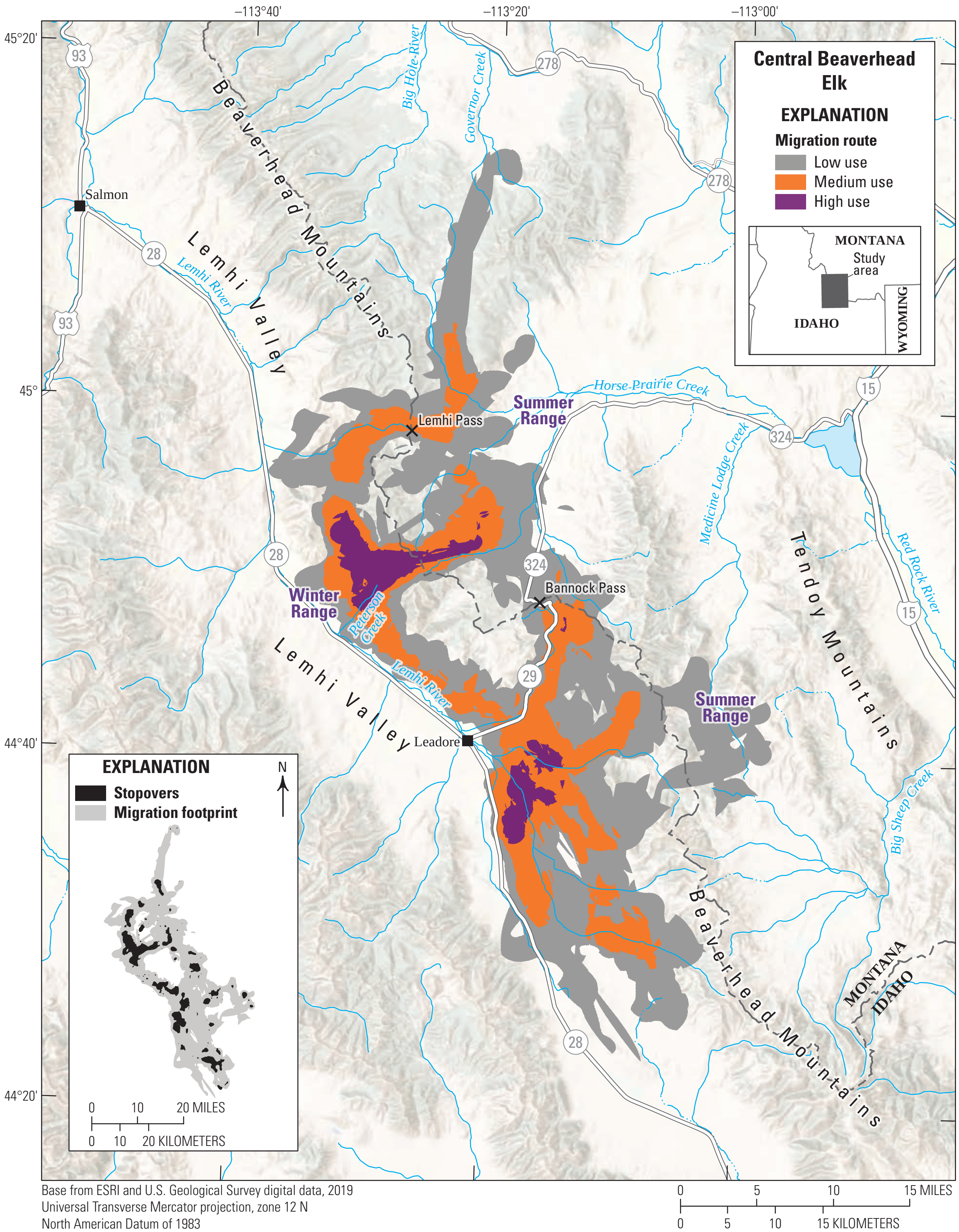


Figure 50. Migration routes and stopovers of the Central Beaverhead elk herd.

Idaho | Elk

Central Beaverhead Elk

The Central Beaverhead elk herd use wintering areas spread across the Lemhi Valley in Idaho. During more severe winters, elk move down the valley and concentrate at lower elevations (fig. 50). Elk migrate across the Beaverhead Mountains to summer in and around the Big Hole River, Horse Prairie Creek, and Medicine Lodge Creek, with some individuals traveling as far as the Red Rock River valley. Common areas to cross the Idaho–Montana divide include near the headwaters of Peterson Creek in Idaho and Black Canyon Creek in Montana, as well as Lemhi Pass to the north and Bannock Pass to the south. On average, the Central Beaverhead elk travel more than 30 miles to migrate between summer and winter range, with the farthest individuals traveling close to 80 miles. Collar data indicate a significant portion of these elk have low fidelity to specific winter ranges and often use different winter ranges year to year. The population estimate for GMU 30 and 30A (including elk migrating into the Lemhi Valley farther north) was 1,554 elk in 2016, a slight increase of 32 elk since the 2009 estimate. Because the Central Beaverhead elk use both Idaho and Montana lands, management of this shared elk population is complicated. Actions taken in one state can affect elk behavior and management actions in a neighboring state. Weather conditions, hunting pressure, crop depredations, and changes in private land use are likely to affect movement and migration of these elk in the future. Conflict between elk and agricultural operations, predominately cattle ranching, can be severe during harsh winters. Retaining high-quality winter range while working with landowners to minimize conflict is a priority.

Animal Capture and Data Collection

Sample size: 59 female elk
Relocation frequency: 13–23 hours
Project duration: March 2015–December 2019

Data Analysis

Migration and stopover analysis: Brownian bridge movement models (Sawyer and others, 2009); Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 101 sequences from 59 individuals (69 spring sequences, 32 fall sequences)

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: April 18 to May 7
- Fall: October 8 to November 7

Average number of days migrating:

- Spring: 26 days
- Fall: 21 days

Migration length:

- Minimum: 4.7 mi (7.6 km)
- Mean: 30.5 mi (49.1 km)
- Maximum: 78.9 mi (127.0 km)

Migration area:

- 469,575 acres (190,030 ha) (low use; 10 percent)
- 131,503 acres (53,217 ha) (medium use; 10–20 percent)
- 20,357 acres (8,238 ha) (high use; greater than 20 percent)
- Stopover area: 54,099 acres (21,893 ha)

Other Information

Project contacts:

- Mark Hurley (mark.hurley@idfg.idaho.gov), Wildlife Research Supervisor, Idaho Department of Fish and Game
- Dennis Newman (dennis.newman@idfg.idaho.gov), Regional Wildlife Manager, Idaho Department of Fish and Game

Data analysts:

- Jodi Berg, Senior Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming
- Scott Bergen, Senior Wildlife Research Biologist, Idaho Department of Fish and Game

Reports and publications:

- Ellstrom, M., Hickey, C., Ward, R., Berkley, R., McDonald, M., Lockyer, Z., Hendricks, C., Painter, G., Roche, E., Elmer, M., and Smith, D., 2019, Mule deer surveys and inventories statewide report 2018 seasons: Boise, Idaho, Idaho Department of Fish and Game, 117 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/Mule%20Deer%20Statewide%20FY2019.pdf.]
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game, 49 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/ID%20F16AF00908%20Statewide%20Wildlife%20Research%20Report%20FY18.pdf.]

Photograph from Idaho Department of Fish and Game.

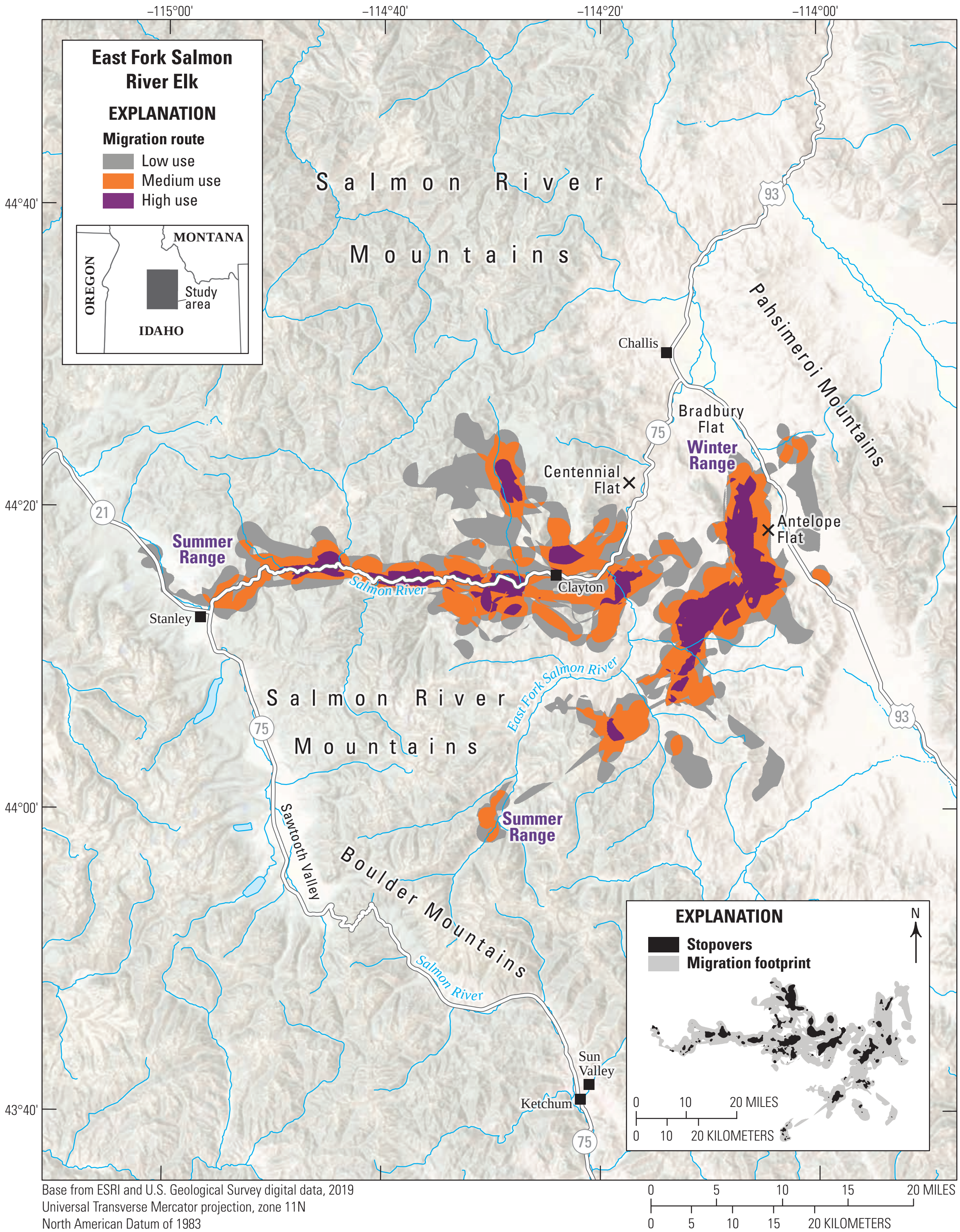


Figure 51. Migration routes and stopovers of the East Fork Salmon River elk herd.

Idaho | Elk

East Fork Salmon River Elk

The East Fork Salmon River elk herd winters east of the Salmon River between Bradbury and Antelope Flats in Idaho (fig. 51). Elk travel the Salmon River and East Fork Salmon River to reach summer ranges in the Salmon River Mountains and the Sawtooth Valley. On average, elk in this population travel 38 miles, with some individuals traveling as far as 84 miles. The population estimate for GMU 36A was about 5,300 elk in 2017. The migration route along the main stem of the Salmon River follows Highway 75 closely and does result in mortalities from wildlife-vehicle collisions.

Animal Capture and Data Collection

Sample size: 24 female elk
Relocation frequency: 1–23 hours
Project duration: November 2008–December 2019

Data Analysis

Migration and stopover analysis: Brownian bridge movement models (Sawyer and others, 2009); Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 67 sequences from 24 individuals (38 spring sequences, 29 fall sequences)

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: April 18 to May 23
- Fall: November 16 to December 28

Average number of days migrating:

- Spring: 31 days
- Fall: 31 days

Migration length:

- Minimum: 11.2 mi (18.0 km)
- Mean: 38.4 mi (61.8 km)
- Maximum: 84.4 mi (135.8 km)

Migration area:

- 433,651 acres (175,492 ha) (low use; 10 percent)
- 175,782 acres (71,137 ha) (medium use; 10–20 percent)
- 41,958 acres (16,980 ha) (high use; greater than 20 percent)
- Stopover area: 48,607 acres (19,671 ha)

Other Information

Project contacts:

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- Dennis Newman (dennis.newman@idfg.idaho.gov), Regional Wildlife Manager, Idaho Department of Fish and Game

Data analysts:

- Jodi Berg, Senior Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming
- Scott Bergen, Senior Wildlife Research Biologist, Idaho Department of Fish and Game

Reports and publications:

- Ellstrom, M., Hickey, C., Ward, R., Berkley, R., McDonald, M., Lockyer, Z., Hendricks, C., Painter, G., Roche, E., Elmer, M., and Smith, D., 2019, Mule deer surveys and inventories statewide report 2018 seasons: Boise, Idaho, Idaho Department of Fish and Game, 117 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/Mule%20Deer%20Statewide%20FY2019.pdf.]
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game, 49 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/ID%20F16AF00908%20Statewide%20Wildlife%20Research%20Report%20FY18.pdf.]

Photograph from Idaho Department of Fish and Game.

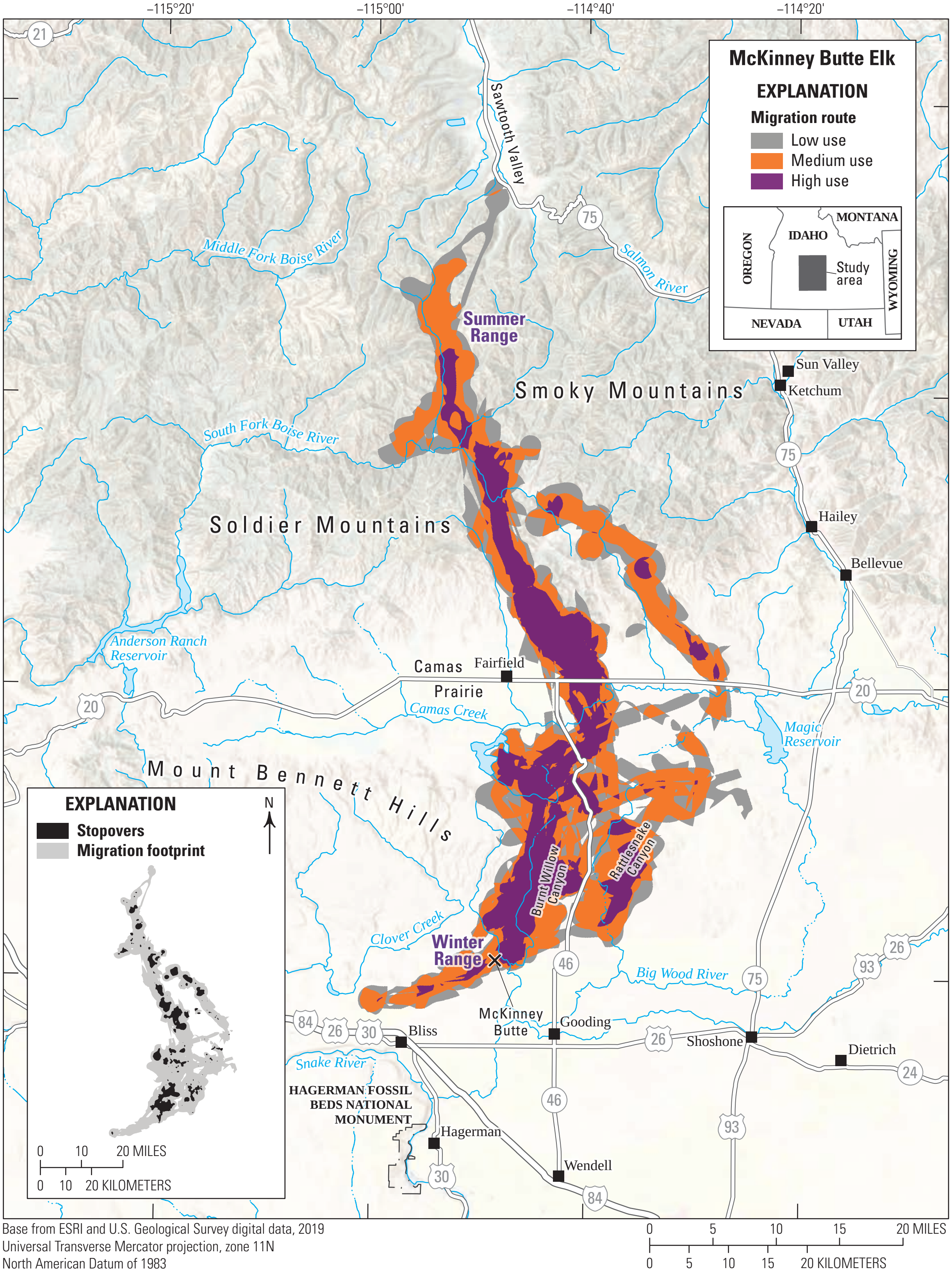


Figure 52. Migration routes and stopovers of the McKinney Butte elk herd.

Idaho | Elk

McKinney Butte Elk

The McKinney Butte elk herd winters north of Bliss and the Snake River near McKinney Butte in Idaho. The McKinney Butte elk herd typically travels north following Burnt Willow and Rattlesnake canyons across the Mount Bennett Hills and Camas Prairie to reach summer ranges in the Smoky Mountains (fig. 52). Some individuals may travel as far as the Sawtooth Valley. On average, elk in this population travel 57 miles, with some individuals traveling as far as 98 miles. These animals are part of the broader Smoky-Bennett elk population, which was estimated by aerial survey to be 3,622 elk in 2021, down from 4,874 elk counted in 2015. Wildfire and the establishment of invasive species, such as medusahead and cheatgrass, have compromised portions of the winter range used by this herd. Additionally, U.S. Highway 20, which serves as a connector route between Boise and Sun Valley, has seen increasing traffic volumes and an elevated risk of wildlife-vehicle collisions.

Animal Capture and Data Collection

Sample size: 23 female elk
Relocation frequency: 20 minutes–23 hours
Project duration: March 2015–January 2020

Data Analysis

Migration and stopover analysis: Brownian bridge movement models (Sawyer and others, 2009); Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 44 sequences from 23 individuals (21 spring sequences, 23 fall sequences)

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: March 16 to May 8
- Fall: November 11 to December 23

Average number of days migrating:

- Spring: 47 days
- Fall: 41 days

Migration length:

- Minimum: 15.3 mi (24.6 km)
- Mean: 57.3 mi (92.2 km)
- Maximum: 98.3 mi (158.2 km)

Migration area:

- 677,614 acres (274,221 ha) (low use; 10 percent)
- 344,094 acres (139,250 ha) (medium use; 10–20 percent)
- 100,844 acres (40,810 ha) (high use; greater than 20 percent)
- Stopover area: 57,891 acres (23,428 ha)

Other Information

Project contacts:

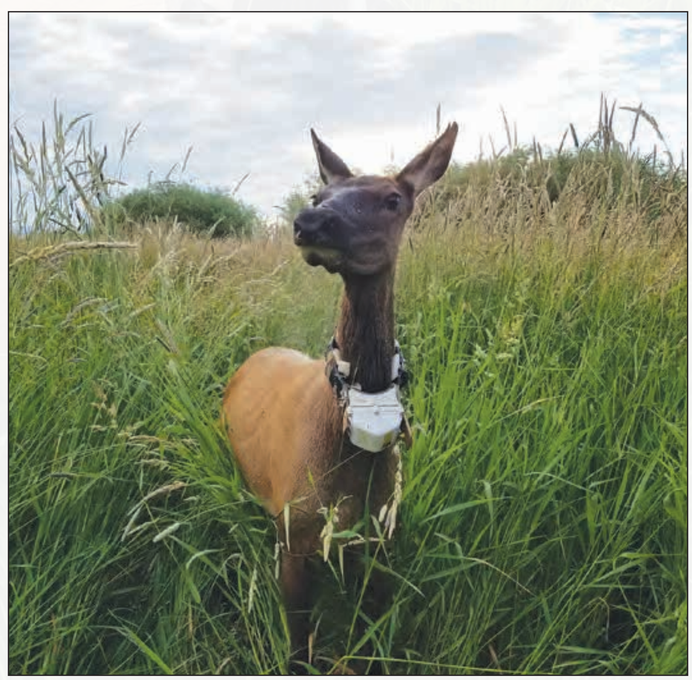
- Mark Hurley (mark.hurley@idfg.idaho.gov), Wildlife Research Supervisor, Idaho Department of Fish and Game
- Mike McDonald (mike.mcdonald@idfg.idaho.gov), Regional Wildlife Manager, Idaho Department of Fish and Game

Data analysts:

- Jodi Berg, Senior Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming
- Scott Bergen, Senior Wildlife Research Biologist, Idaho Department of Fish and Game

Reports and publications:

- Ellstrom, M., Hickey, C., Ward, R., Berkley, R., McDonald, M., Lockyer, Z., Hendricks, C., Painter, G., Roche, E., Elmer, M., and Smith, D., 2019, Mule deer surveys and inventories statewide report 2018 seasons: Boise, Idaho, Idaho Department of Fish and Game, 117 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/Mule%20Deer%20Statewide%20FY2019.pdf.]
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game, 49 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/ID%20F16AF00908%20Statewide%20Wildlife%20Research%20Report%20FY18.pdf.]



Photograph from Brett Panting, Idaho Department of Fish and Game.

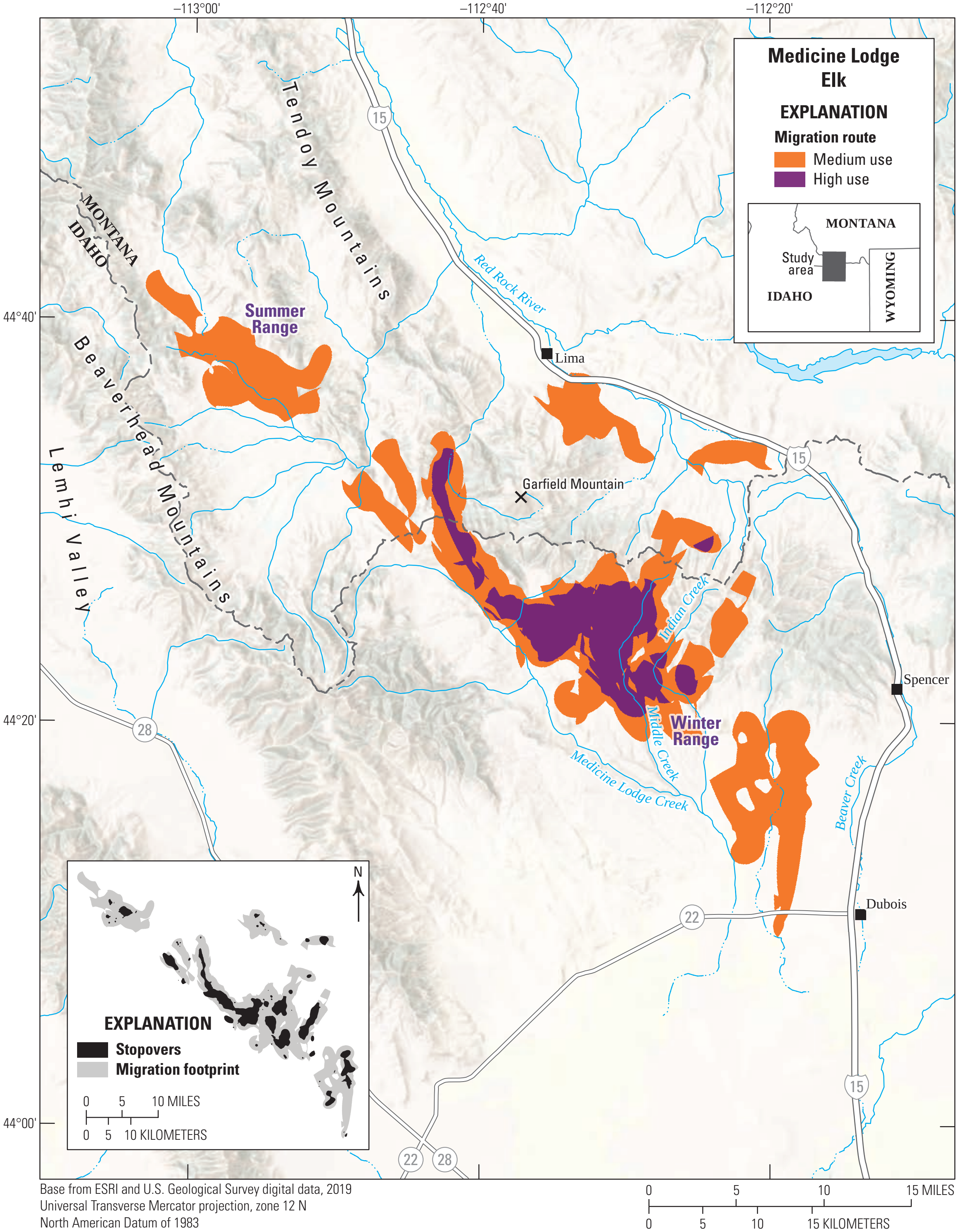


Figure 53. Migration routes and stopovers of the Medicine Lodge elk herd.

Idaho | Elk

Medicine Lodge Elk

Wintering concentrations for the Medicine Lodge elk herd are northwest of Dubois, Idaho (fig. 53). Habitat types are typically comprised of sagebrush and grasslands on southerly slopes, Douglas fir on most northern aspects, and aspen and willow communities in many of the riparian zones. Other mountain shrub species and aspen communities tend to increase towards Pleasant Valley. Elk in the area typically follow the Medicine Lodge Creek valley up to summer ranges in the Tendoy and Beaverhead Mountains, with some individuals spending time in the Red Rock River valley. On average, elk in this population travel 25 miles, with some individuals traveling as far as 62 miles. Elk abundance was low in this area throughout most of the 1900s. Elk immigrated into the Medicine Lodge Creek area from other populations in Idaho and Montana, and the population reached a level in 1988 that IDFG determined was large enough to support antlerless harvest. The Medicine Lodge population has continued to increase gradually, reaching 1,370 elk in 2016. This herd was described by the DOI 2014–2024 Elk Plan as being moderately limited by agricultural effects. The most common conflicts are depredation of actively growing alfalfa fields during summer and haystack depredations during winter. In addition, a bison livestock operation built a livestock-proof fence on private lands in GMU 59 and 59A, resulting in a significant barrier to elk movement in core habitat. Loss of habitat because of fire also affected large portions of this population's winter range and continues to be a concern. Lastly, overall use of this area from multiple user groups, especially with regards to expansion of both legal and illegal recreational motorized vehicle use, presents continuing management challenges related to habitat quality and quantity.

Animal Capture and Data Collection

Sample size: 20 female elk
Relocation frequency: 13–23 hours
Project duration: March 2015–June 2019

Data Analysis

Migration and stopover analysis: Brownian bridge movement models (Sawyer and others, 2009); Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 38 sequences from 20 individuals (28 spring sequences, 10 fall sequences)

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: April 3 to April 23
- Fall: November 23 to December 23

Average number of days migrating:

- Spring: 21 days
- Fall: 16 days

Migration length:

- Minimum: 9.4 mi (15.1 km)
- Mean: 25.4 mi (40.9 km)
- Maximum: 62.1 mi (99.9 km)

Migration area:

- 165,857 acres (67,120 ha) (medium use; 10–20 percent)
- 30,303 acres (12,263 ha) (high use; greater than 20 percent)
- Stopover area: 32,405 acres (13,114 ha)

Other Information

Project contacts:

- Mark Hurley (mark.hurley@idfg.idaho.gov), Wildlife Research Supervisor, Idaho Department of Fish and Game
- Curtis Hendricks (curtis.hendricks@idfg.idaho.gov), Regional Wildlife Manager, Idaho Department of Fish and Game

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- Scott Bergen, Senior Wildlife Research Biologist, Idaho Department of Fish and Game

Reports and publications:

- Ellstrom, M., Hickey, C., Ward, R., Berkley, R., McDonald, M., Lockyer, Z., Hendricks, C., Painter, G., Roche, E., Elmer, M., and Smith, D., 2019, Mule deer surveys and inventories statewide report 2018 seasons: Boise, Idaho, Idaho Department of Fish and Game, 117 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/Mule%20Deer%20Statewide%20FY2019.pdf.]
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game, 49 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/ID%20F16AF00908%20Statewide%20Wildlife%20Research%20Report%20FY18.pdf.]

Photograph from James Brower, Idaho Department of Fish and Game.

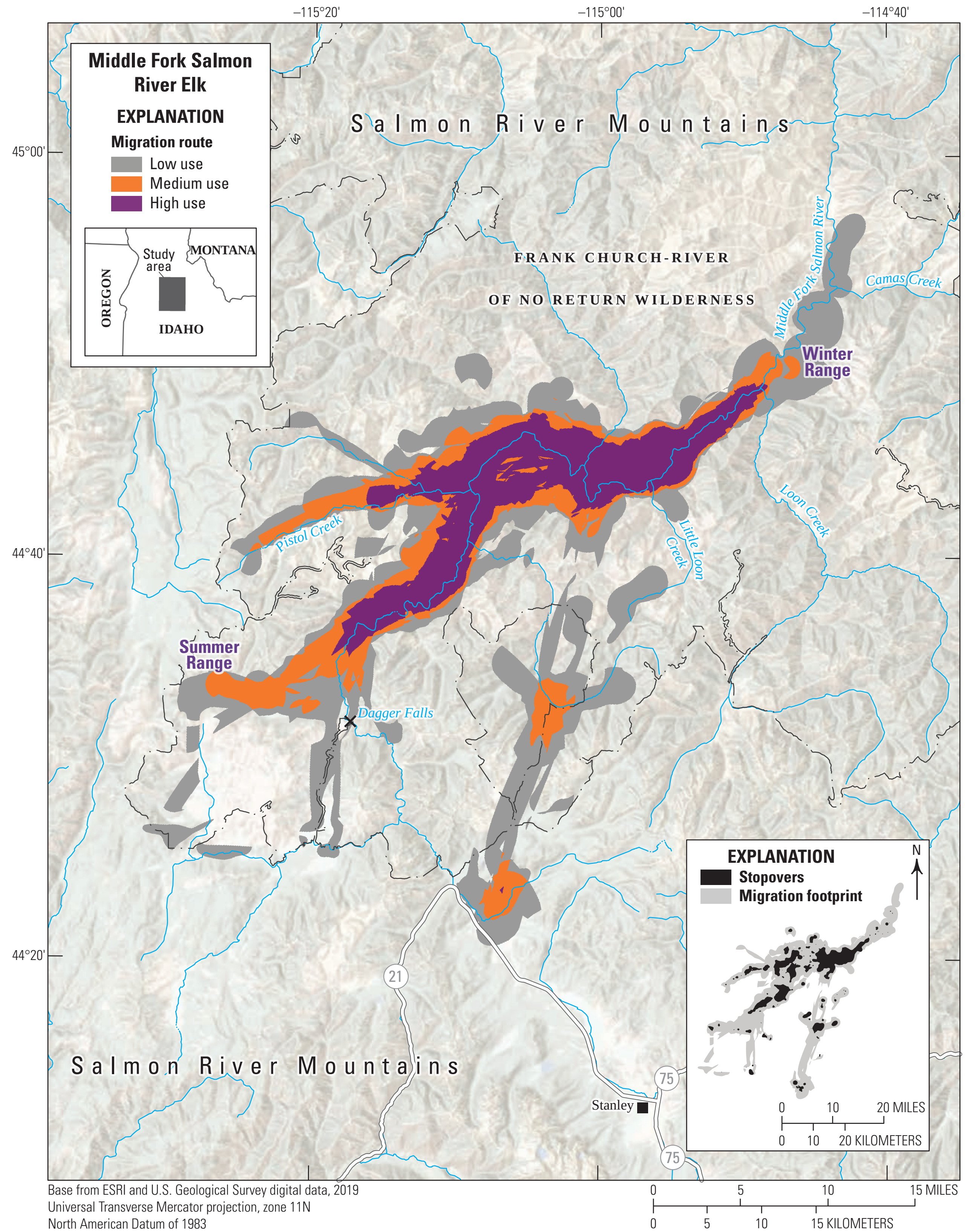

Figure 54. Migration routes and stopovers of the Middle Fork Salmon River elk herd.

Idaho | Elk

Middle Fork Salmon River Elk

The Middle Fork Salmon River elk herd winters at the lower elevations along the Middle Fork Salmon River in Idaho (fig. 54). In spring, the elk generally follow the Middle Fork Salmon River upstream towards Dagger Falls to their summer range in the Salmon River Mountains. However, some of the elk branch off into the larger tributaries such as Pistol and Little Loon Creeks. This population of elk resides almost entirely on public land, largely within the Frank Church-River of No Return Wilderness. On average, Middle Fork Salmon River elk herd travels 25 miles, with some individuals traveling as far as 62 miles. These elk belong to the Middle Fork Elk Zone, which had a population estimate of 4,860 elk in 2017.

Animal Capture and Data Collection

Sample size: 32 female elk
Relocation frequency: 2–23 hours
Project duration: October 2020–June 2018

Data Analysis

Migration and stopover analysis: Brownian bridge movement models (Sawyer and others, 2009); Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 70 sequences from 32 individuals (47 spring sequences, 23 fall sequences)

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: April 20 to May 29
- Fall: October 24 to December 14

Average number of days migrating:

- Spring: 34 days
- Fall: 38 days

Migration length:

- Minimum: 8.1 mi (13.0 km)
- Mean: 35.8 mi (57.6 km)
- Maximum: 63.0 mi (101.4 km)

Migration area:

- 373,845 acres (151,290 ha) (low use; 10 percent)
- 155,836 acres (63,065 ha) (medium use; 10–20 percent)
- 55,555 acres (22,482 ha) (high use; greater than 20 percent)
- Stopover area: 48,778 acres (19,740 ha)

Other Information

Project contacts:

- Mark Hurley (mark.hurley@idfg.idaho.gov), Wildlife Research Supervisor, Idaho Department of Fish and Game
- Dennis Newman (dennis.newman@idfg.idaho.gov), Regional Wildlife Manager, Idaho Department of Fish and Game

Data analysts:

- Jodi Berg, Senior Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming
- Scott Bergen, Senior Wildlife Research Biologist, Idaho Department of Fish and Game

Reports and publications:

- Ellstrom, M., Hickey, C., Ward, R., Berkley, R., McDonald, M., Lockyer, Z., Hendricks, C., Painter, G., Roche, E., Elmer, M., and Smith, D., 2019, Mule deer surveys and inventories statewide report 2018 seasons: Boise, Idaho, Idaho Department of Fish and Game, 117 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/Mule%20Deer%20Statewide%20FY2019.pdf.]
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game, 49 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/ID%20F16AF00908%20Statewide%20Wildlife%20Research%20Report%20FY18.pdf.]

Photograph from Idaho Department of Fish and Game.

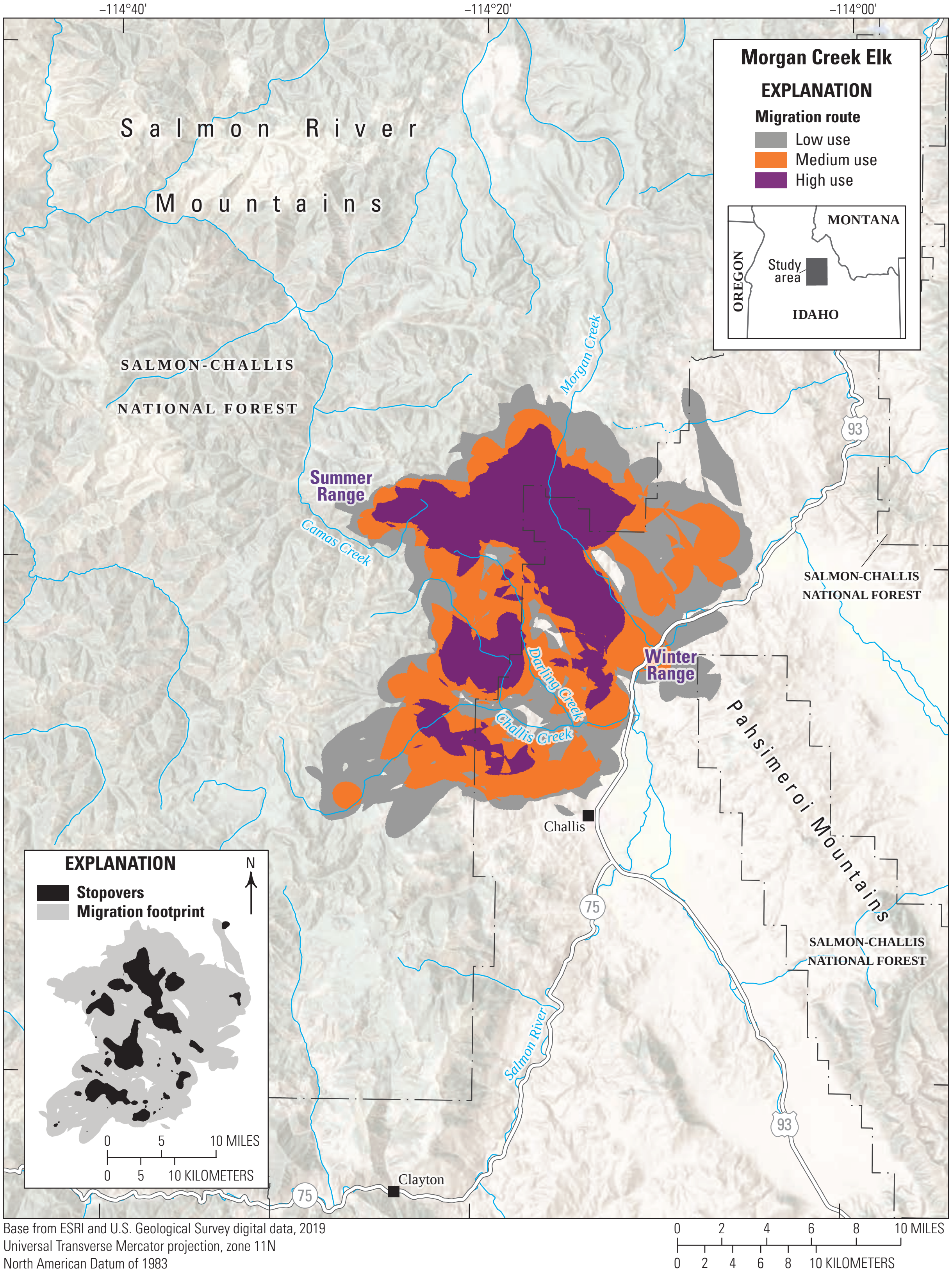

Figure 55. Migration routes and stopovers of the Morgan Creek elk herd.

Idaho | Elk

Morgan Creek Elk

The Morgan Creek elk herd uses areas of the foothills north of the Challis, Idaho, in winter. The winter range is primarily on public land, but there is some use of private agricultural land on the valley floor (fig. 55). After the snow melts, elk migrate west, fanning out into the Salmon River Mountains. Most of the elk migrate through the main drainages of Challis, Darling, and Morgan Creeks. The summer range is almost entirely on public land in the Salmon-Challis National Forest. On average, the Morgan Creek elk herd travels more than 25 miles to migrate between summer and winter ranges with more extensive migrations reaching more than 67 miles. The wintering population of elk used for this analysis is part of the Salmon Elk Zone, which had an estimated population of 9,955 elk in 2016.

Animal Capture and Data Collection

Sample size: 34 female elk
Relocation frequency: 1–23 hours
Project duration: March 2015–December 2019

Data Analysis

Migration and stopover analysis: Brownian bridge movement models (Sawyer and others, 2009); Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 88 sequences from 34 individuals (52 spring sequences, 36 fall sequences)

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: April 1 to May 22
- Fall: October 23 to December 3

Average number of days migrating:

- Spring: 44 days
- Fall: 33 days

Migration length:

- Minimum: 5.6 mi (9.0 km)
- Mean: 25.4 mi (40.9 km)
- Maximum: 67.0 mi (107.8 km)

Migration area:

- 284,957 acres (115,318 ha) (low use; 10 percent)
- 137,246 acres (55,542 ha) (medium use; 10–20 percent)
- 42,620 acres (17,248 ha) (high use; greater than 20 percent)
- Stopover area: 27,198 acres (11,007 ha)

Other Information

Project contacts:

- Mark Hurley (mark.hurley@idfg.idaho.gov), Wildlife Research Supervisor, Idaho Department of Fish and Game
- Dennis Newman (dennis.newman@idfg.idaho.gov), Regional Wildlife Manager, Idaho Department of Fish and Game

Data analysts:

- Jodi Berg, Senior Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming
- Scott Bergen, Senior Wildlife Research Biologist, Idaho Department of Fish and Game

Reports and publications:

- Ellstrom, M., Hickey, C., Ward, R., Berkley, R., McDonald, M., Lockyer, Z., Hendricks, C., Painter, G., Roche, E., Elmer, M., and Smith, D., 2019, Mule deer surveys and inventories statewide report 2018 seasons: Boise, Idaho, Idaho Department of Fish and Game, 117 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/Mule%20Deer%20Statewide%20FY2019.pdf.]
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game, 49 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/ID%20F16AF00908%20Statewide%20Wildlife%20Research%20Report%20FY18.pdf.]

Photograph from Idaho Department of Fish and Game.

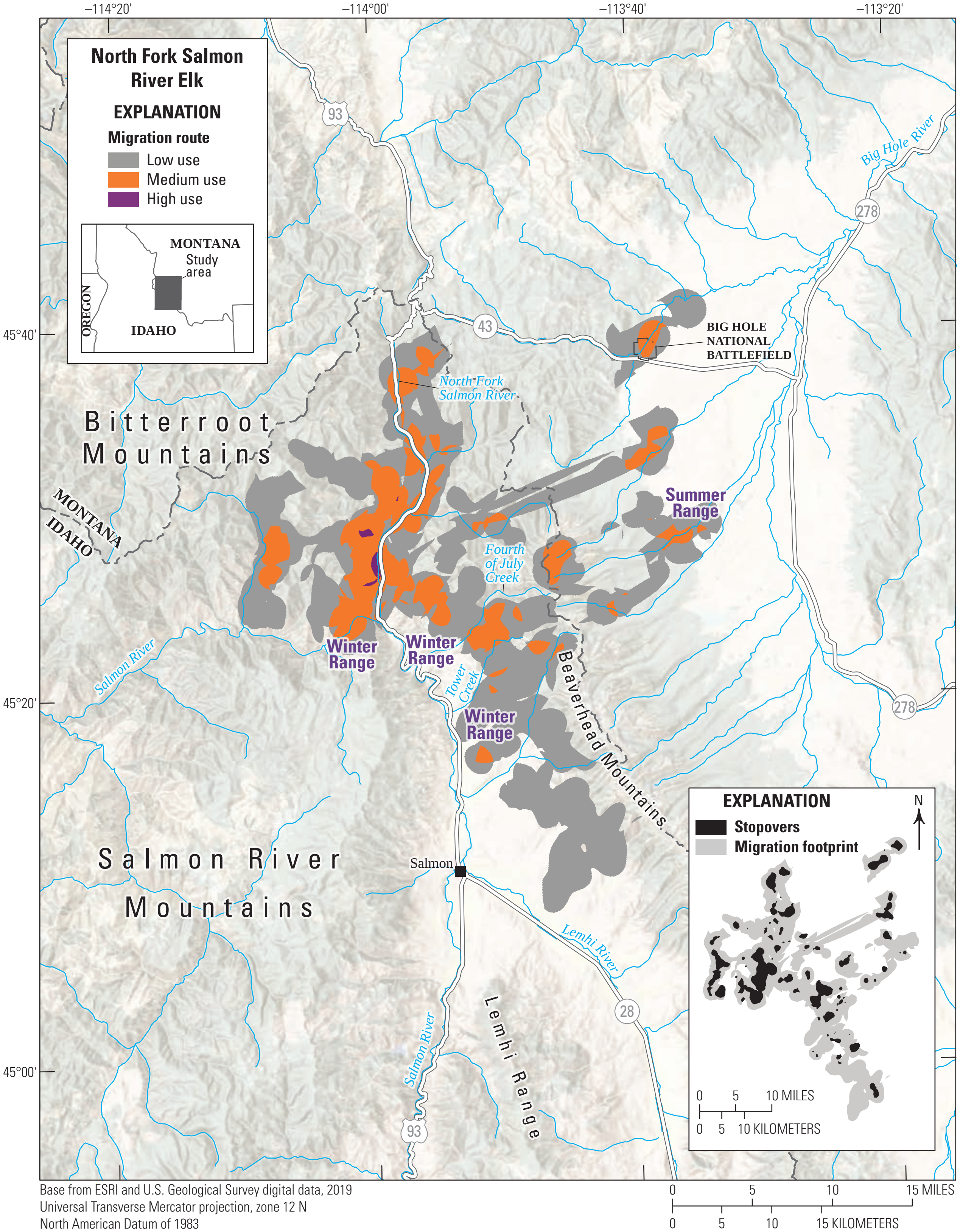

Figure 56. Migration routes and stopovers of the North Fork Salmon River elk herd.

Idaho | Elk

North Fork Salmon River Elk

The North Fork Salmon River elk herd originate primarily from the Salmon Elk Zone with some elk at the most southerly portion originating from the Beaverhead Elk Zone in Idaho (fig. 56). These elk winter in the foothills of the Beaverhead Mountains and along the Salmon River valley between North Fork and Salmon, Idaho. They fan out across higher elevations of the Bitterroot Mountains, where some travel northeast towards summer ranges in the Big Hole River valley in Montana. On average, North Fork Salmon River elk travel 25 miles to migrate between summer and winter ranges, with more extensive migrations reaching more than 57 miles. Because they initiate migration in April, these elk encounter relatively deep snow when crossing the mountains into Montana. The wintering population of elk used for this analysis approximated 3,800 in 2016.

Animal Capture and Data Collection

Sample size: 36 female elk
Relocation frequency: 13–23 hours
Project duration: March 2015–December 2019

Data Analysis

Migration and stopover analysis: Brownian bridge movement models (Sawyer and others, 2009); Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 74 sequences from 36 individuals (40 spring sequences, 34 fall sequences)

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: April 18 to May 14
- Fall: October 31 to November 9

Average number of days migrating:

- Spring: 25 days
- Fall: 29 days

Migration length:

- Minimum: 4.7 mi (7.6 km)
- Mean: 24.5 mi (39.4 km)
- Maximum: 57.7 mi (92.9 km)

Migration area:

- 249,764 acres (101,076 ha) (low use; 10 percent)
- 45,535 acres (18,427 ha) (medium use; 10–20 percent)
- 895 acres (350 ha) (high use; greater than 20 percent)
- Stopover area: 39,188 acres (15,859 ha)

Other Information

Project contacts:

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- Dennis Newman (dennis.newman@idfg.idaho.gov), Regional Wildlife Manager, Idaho Department of Fish and Game

Data analysts:

- Jodi Berg, Senior Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming
- Scott Bergen, Senior Wildlife Research Biologist, Idaho Department of Fish and Game

Reports and publications:

- Ellstrom, M., Hickey, C., Ward, R., Berkley, R., McDonald, M., Lockyer, Z., Hendricks, C., Painter, G., Roche, E., Elmer, M., and Smith, D., 2019, Mule deer surveys and inventories statewide report 2018 seasons: Boise, Idaho, Idaho Department of Fish and Game, 117 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/Mule%20Deer%20Statewide%20FY2019.pdf.]
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game, 49 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/ID%20F16AF00908%20Statewide%20Wildlife%20Research%20Report%20FY18.pdf.]

Photograph from Idaho Department of Fish and Game.

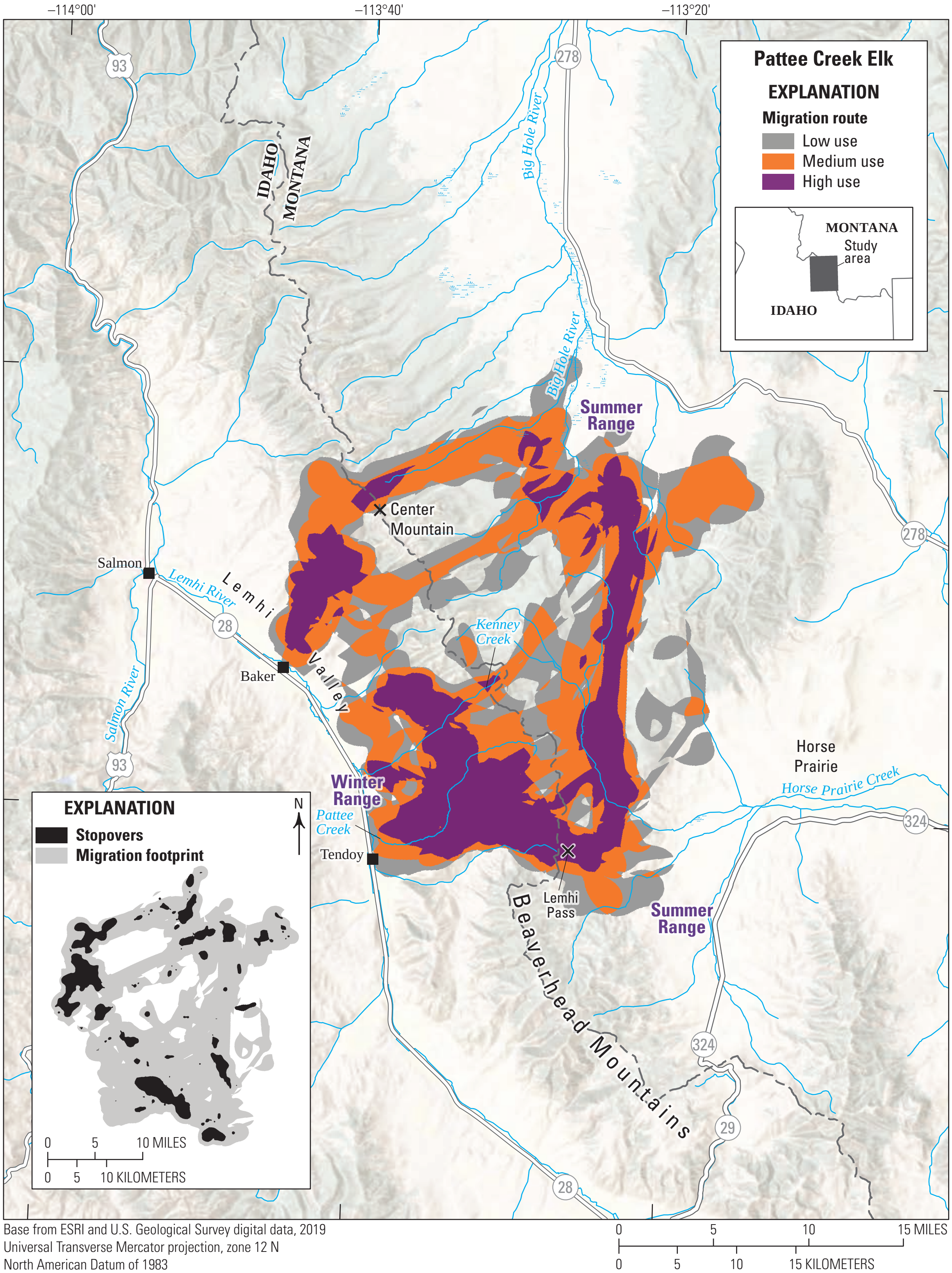

Figure 57. Migration routes and stopovers of the Pattee Creek elk herd.

Idaho | Elk

Pattee Creek Elk

The Pattee Creek elk herd winters in the Lemhi Valley between Baker and Tendoy, Idaho. These elk generally migrate east and north across the Beaverhead Mountains to summer near the Big Hole River valley in Montana (fig. 57). Common areas to cross the Idaho–Montana divide include the headwaters of Kenney Creek, Lemhi Pass to the south, and Center Mountain to the north. On average, the Pattee Creek elk herd travels more than 32 miles to migrate between summer and winter ranges, with more extensive migrations measuring more than 80 miles. Collar data indicate a significant portion of these elk have low fidelity to specific winter ranges and often use different winter ranges year to year. The population estimate for GUMs 30 and 30A (including elk that migrate into the Lemhi Valley farther south) was 1,554 elk in 2016. Elk in this area use both Idaho and Montana lands, and management of this shared elk population is more complicated. Actions taken in one state can affect elk behavior and management actions in a neighboring state. Weather conditions, hunting pressure, crop depredations, and changes in private land use are likely to affect movement and migration of these elk in the future. During more severe winters, elk become concentrated at lower elevations in the Lemhi Valley, where they can conflict with private agricultural lands. Conflict between elk and agricultural operations, predominately cattle ranching, can be severe during harsh winters. Retaining high-quality winter range while minimizing conflict with landowners is a priority.

Animal Capture and Data Collection

Sample size: 22 female elk
Relocation frequency: 13–23 hours
Project duration: March 2015–December 2019

Data Analysis

Migration and stopover analysis: Brownian bridge movement models (Sawyer and others, 2009); Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 68 sequences from 22 individuals (37 spring sequences, 31 fall sequences)

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: April 17 to May 15
- Fall: September 25 to October 22

Average number of days migrating:

- Spring: 23 days
- Fall: 29 days

Migration length:

- Minimum: 8.3 mi (13.4 km)
- Mean: 32.4 mi (52.1km)
- Maximum: 80.7 mi (129.9 km)

Migration area:

- 474,877 acres (192,176 ha) (low use; 10 percent)
- 236,931 acres (95,883 ha) (medium use; 10–20 percent)
- 2,858 acres (29,485 ha) (high use; greater than 20 percent)
- Stopover area: 37,969 acres (15,366 ha)

Other Information

Project contacts:

- Mark Hurley (mark.hurley@idfg.idaho.gov), Wildlife Research Supervisor, Idaho Department of Fish and Game
- Dennis Newman (dennis.newman@idfg.idaho.gov), Regional Wildlife Manager, Idaho Department of Fish and Game

Data analysts:

- Jodi Berg, Senior Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming
- Scott Bergen, Senior Wildlife Research Biologist, Idaho Department of Fish and Game

Reports and publications:

- Ellstrom, M., Hickey, C., Ward, R., Berkley, R., McDonald, M., Lockyer, Z., Hendricks, C., Painter, G., Roche, E., Elmer, M., and Smith, D., 2019, Mule deer surveys and inventories statewide report 2018 seasons: Boise, Idaho, Idaho Department of Fish and Game, 117 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/Mule%20Deer%20Statewide%20FY2019.pdf.]
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game, 49 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/ID%20F16AF00908%20Statewide%20Wildlife%20Research%20Report%20FY18.pdf.]

Photograph from Idaho Department of Fish and Game.

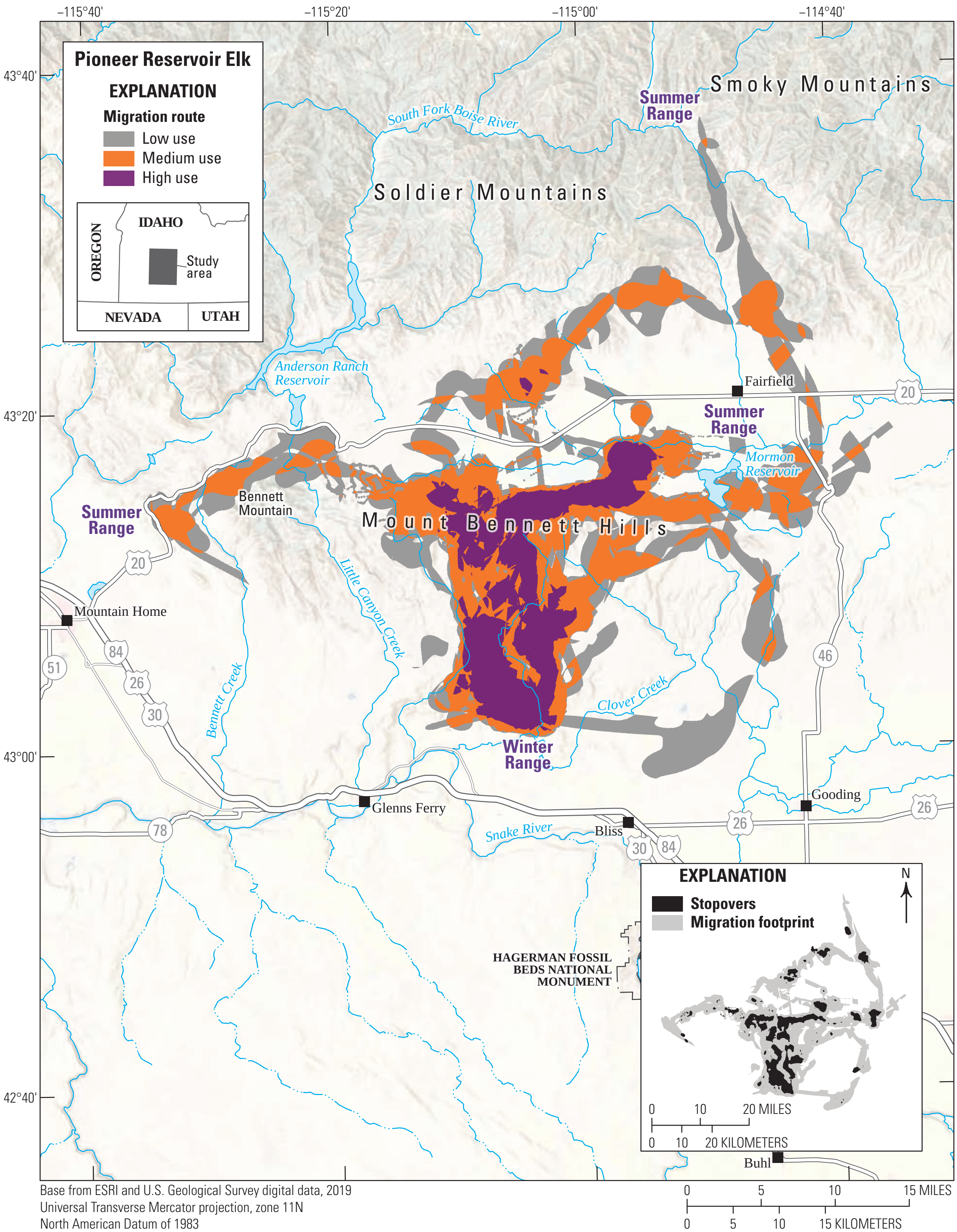

Figure 58. Migration routes and stopovers of the Pioneer Reservoir elk herd.

Idaho | Elk

Pioneer Reservoir Elk

The Pioneer Reservoir elk herd winters east of Mountain Home, Idaho, in vicinity of the confluence between Clover Creek and the Snake River (fig. 58). They migrate north-northeast past Mormon Reservoir and Camas Creek to summer in the Soldier Mountains. On average, these elk travel more than 53 miles to migrate between summer and winter ranges with some individuals traveling more than 104 miles. These animals are part of the broader Smoky-Bennett elk population, which was estimated by aerial survey to be 3,622 elk in 2021, down from 4,874 elk in 2015. Seasonal movement pathways of the Pioneer Reservoir elk may be affected by energy development and transportation infrastructure, whereas winter habitats are changing because of fire and the proliferation of exotic annual grasses.

Animal Capture and Data Collection

Sample size: 30 female elk
Relocation frequency: 20 minutes–23 hours
Project duration: March 2015–January 2020

Data Analysis

Migration and stopover analysis: Brownian bridge movement models (Sawyer and others, 2009); Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 42 sequences from 30 individuals (31 spring sequences, 11 fall sequences)

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: March 26 to April 24
- Fall: October 10 to December 9

Average number of days migrating:

- Spring: 41 days
- Fall: 51 days

Migration length:

- Minimum: 22.1 mi (35.6 km)
- Mean: 53.4 mi (85.9 km)
- Maximum: 104.6 mi (168.3 km)

Migration area:

- 551,064 acres (223,008 ha) (low use; 10 percent)
- 238,880 acres (96,671 ha) (medium use; 10–20 percent)
- 62,182 acres (25,164 ha) (high use; greater than 20 percent)
- Stopover area: 64,944 acres (26,282 ha)

Other Information

Project contacts:

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- Mike McDonald (mike.mcdonald@idfg.idaho.gov), Regional Wildlife Manager, Idaho Department of Fish and Game

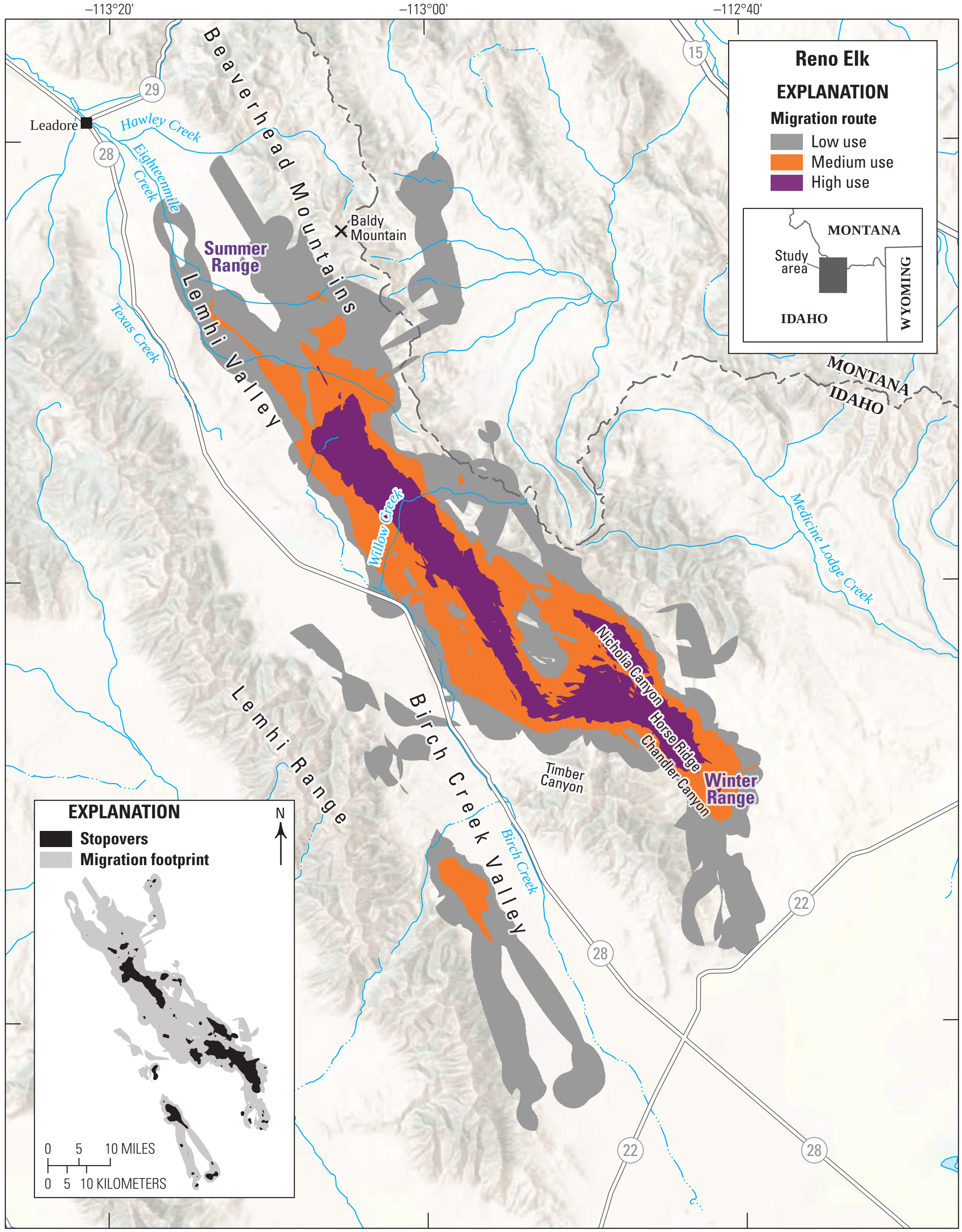
Data analysts:

- Jodi Berg, Senior Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming
- Scott Bergen, Senior Wildlife Research Biologist, Idaho Department of Fish and Game

Reports and publications:

- Ellstrom, M., Hickey, C., Ward, R., Berkley, R., McDonald, M., Lockyer, Z., Hendricks, C., Painter, G., Roche, E., Elmer, M., and Smith, D., 2019, Mule deer surveys and inventories statewide report 2018 seasons: Boise, Idaho, Idaho Department of Fish and Game, 117 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/Mule%20Deer%20Statewide%20FY2019.pdf.]
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game, 49 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/ID%20F16AF00908%20Statewide%20Wildlife%20Research%20Report%20FY18.pdf.]

Photograph from Rick Ward, Idaho Department of Fish and Game.



Base from ESRI and U.S. Geological Survey digital data, 2019
Universal Transverse Mercator projection, zone 12 N
North American Datum of 1983

Figure 59. Migration routes and stopovers of the Reno elk herd.

Idaho | Elk

Reno Elk

The Reno elk herd winters at the southern end of the Beaverhead Mountains in Idaho (fig. 59). The Reno Elk herd migrates north along the Beaverhead Mountains to reach summer ranges near Baldy Mountain, Texas Creek, and Eighteenmile Creek. Habitat is sagebrush and mixed grasses on south-facing slopes with mountain mahogany at lower elevations. Douglas fir communities occur on northern-facing slopes, and riparian areas are typically dominated by willow and more mesic species with occasional aspen stands. Limber pine is not uncommon at upper elevations near tree line. On average, Reno elk migrate 32 miles and may migrate as far as 79 miles. Elk abundance was low in this area throughout most of the 1900s. Elk immigrated into the Reno area from other populations in Idaho and Montana, and the population reached a level in 1988 that IDFG determined was large enough to support antlerless harvest. The Reno elk population has continued to increase gradually and was estimated to be 2,100 elk in 2017. This herd was described by the DOI 2014–2024 Elk Plan as being moderately limited by agricultural effects. The most common conflicts are depredation of actively growing alfalfa fields during summer and haystack depredations during winter, as well as increasing recreational activity during all months of the year. Loss of habitat because of fire also affected large portions of this population's winter range and continues to be a concern. Lastly, overall use of this area from multiple user groups, especially with regards to expansion of both legal and illegal recreational motorized vehicle use, presents continuing management challenges related to habitat quality and quantity.

Animal Capture and Data Collection

Sample size: 44 female elk
Relocation frequency: 13–23 hours
Project duration: March 2015–December 2019

Data Analysis

Migration and stopover analysis: Brownian bridge movement models (Sawyer and others, 2009); Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 72 sequences from 44 individuals (44 spring sequences, 28 fall sequences)

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: March 28 to May 1
- Fall: November 1 to December 2

Average number of days migrating:

- Spring: 21 days
- Fall: 22 days


Photograph from James Brower, Idaho Department of Fish and Game.

Migration length:

- Minimum: 4.1 mi (6.6 km)
- Mean: 32.4 mi (52.1 km)
- Maximum: 79.0 mi (127.1 km)

Migration area:

- 389,512 acres (157,630 ha) (low use; 10 percent)
- 140,419 acres (56,826 ha) (medium use; 10–20 percent)
- 39,037 acres (15,798 ha) (high use; greater than 20 percent)
- Stopover area: 44,159 acres (17,871 ha)

Other Information

Project contacts:

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- Scott Bergen, Senior Wildlife Research Biologist, Idaho Department of Fish and Game

Reports and publications:

- Ellstrom, M., Hickey, C., Ward, R., Berkley, R., McDonald, M., Lockyer, Z., Hendricks, C., Painter, G., Roche, E., Elmer, M., and Smith, D., 2019, Mule deer surveys and inventories statewide report 2018 seasons: Boise, Idaho, Idaho Department of Fish and Game, 117 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/Mule%20Deer%20Statewide%20FY2019.pdf.]
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game, 49 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/ID%20F16AF00908%20Statewide%20Wildlife%20Research%20Report%20FY18.pdf.]

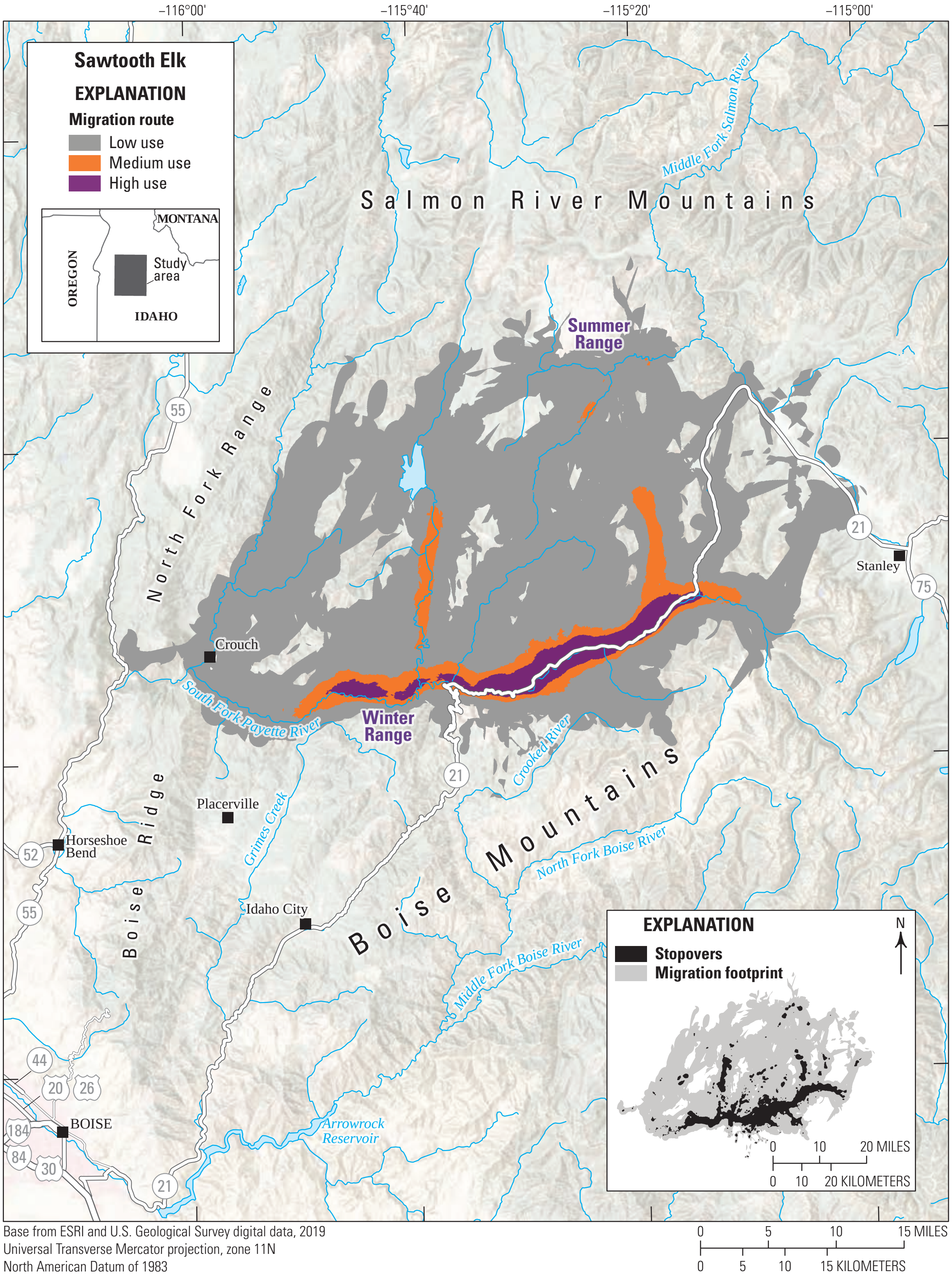

Figure 60. Migration routes and stopovers of the Sawtooth elk herd.

Idaho | Elk

Sawtooth Elk

The Sawtooth elk herd winters along the South Fork Payette River in Idaho (fig. 60). Elk wintering in this area typically migrate north into the Salmon River Mountains east of the Middle Fork Payette River and west of Stanley. On average, Sawtooth elk travel more than 29 miles to migrate between summer and winter range, with the farthest individuals traveling more than 113 miles. The population in the Sawtooth Elk Zone was estimated to be 3,500 elk in 2017.

Animal Capture and Data Collection

Sample size: 218 individual elk
Relocation frequency: 2–23 hours
Project duration: April 2008–February 2020

Data Analysis

Migration and stopover analysis: Brownian bridge movement models (Sawyer and others, 2009); Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 547 sequences from 218 individuals (338 spring sequences, 209 fall sequences)

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: April 28 to May 24
- Fall: October 26 to November 30

Average number of days migrating:

- Spring: 27 days
- Fall: 35 days

Migration length:

- Minimum: 3.0 mi (4.8 km)
- Mean: 29.0 mi (46.7 km)
- Maximum: 113.8 mi (183.1 km)

Migration area:

- 685,180 acres (277,283 ha) (low use; 10 percent)
- 86,940 acres (35,183 ha) (medium use; 10–20 percent)
- 23,568 acres (9,538 ha) (high use; greater than 20 percent)
- Stopover area: 90,014 acres (36,427 ha)

Other Information

Project contacts:

- Mark Hurley (mark.hurley@idfg.idaho.gov), Wildlife Research Supervisor, Idaho Department of Fish and Game
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- Scott Bergen, Senior Wildlife Research Biologist, Idaho Department of Fish and Game

Reports and publications:

- Ellstrom, M., Hickey, C., Ward, R., Berkley, R., McDonald, M., Lockyer, Z., Hendricks, C., Painter, G., Roche, E., Elmer, M., and Smith, D., 2019, Mule deer surveys and inventories statewide report 2018 seasons: Boise, Idaho, Idaho Department of Fish and Game, 117 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/Mule%20Deer%20Statewide%20FY2019.pdf.]
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game, 49 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/ID%20F16AF00908%20Statewide%20Wildlife%20Research%20Report%20FY18.pdf.]


Photograph from Idaho Department of Fish and Game.

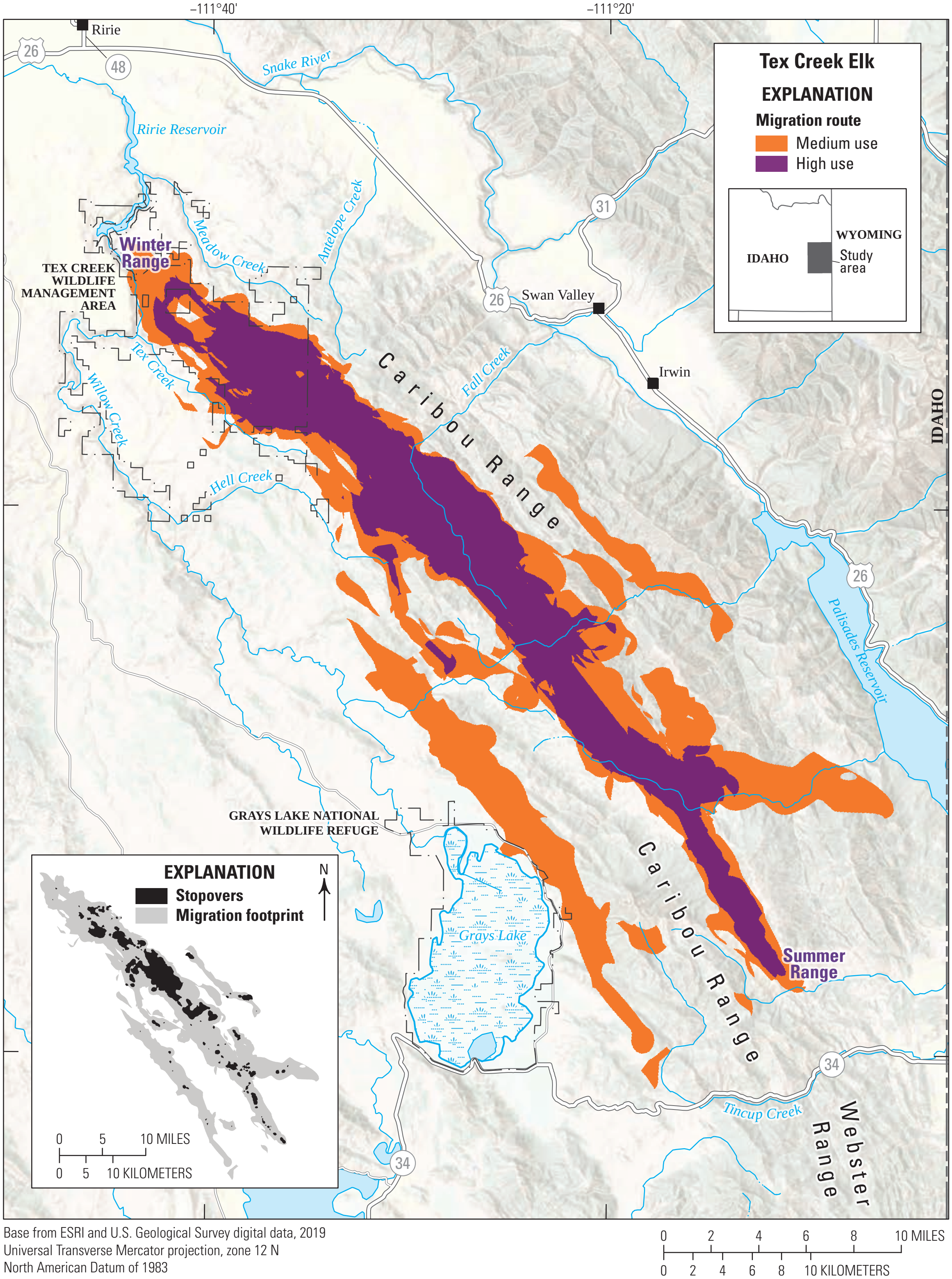


Figure 61. Migration routes and stopovers of the Tex Creek elk herd.

Idaho | Elk

Tex Creek Elk

The Tex Creek elk herd winters in the tributaries of Willow and Meadow Creeks on the northwest end of the Caribou Range, with the majority of elk using the Tex Creek Wildlife Management Area (WMA) in Idaho (fig. 61). Tex Creek WMA and surrounding private lands are varied, consisting of steep, rocky canyon walls, small drainages covered in native vegetation and shrubs, and open benches and flats of native and non-native vegetation. Portions of the winter range have been developed for wind energy. Tex Creek elk migrate southeast to the Caribou Range to summer, traveling 40 miles on average with the longest recorded migration of 63 miles. The wintering population of elk used for this analysis approximated 5,500 in winter 2020–2021 with approximately 4,000 elk using Tex Creek WMA, and the remaining 1,500 elk using public and private lands with lower snow loads in the vicinity of Tex Creek WMA. In 2016, the Henry Creek fire burned approximately 57,000 acres of winter and transitional range associated with the Tex Creek herd. The effect of this fire on elk seems minimal, but the significant loss of healthy shrub habitat likely affected elk distribution and forage availability. Managers continue to monitor habitat and wildlife responses to this fire. Development, expansion of both legal and illegal motorized recreational vehicle use, and overgrazing are threats facing this herd during migration and at wintering and stopover locations. Depredation and private land conflicts are also issues, especially during deep snow years when elk leave the WMA and other public lands and move into adjacent populated areas to the north and west.

Animal Capture and Data Collection

Sample size: 20 female elk
Relocation frequency: 1–6 hours
Project duration: March 2007–January 2009

Data Analysis

Migration and stopover analysis: Brownian bridge movement models (Sawyer and others, 2009); Fixed Motion Variance movement models (see app. 1 for further description)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 48 sequences from 20 individuals (31 spring sequences, 17 fall sequences)

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: March 23 to May 7
- Fall: December 2 to December 22

Average number of days migrating:

- Spring: 35 days
- Fall: 31 days

Migration length:

- Minimum: 0.9 mi (1.4 km)
- Mean: 40.1 mi (64.5 km)
- Maximum: 63.1 mi (101.5 km)

Migration area:

- 197,553 acres (79,947 ha) (medium use; 10–20 percent)
- 60,696 acres (24,563 ha) (high use; greater than 20 percent)
- Stopover area: 23,436 acres (9,484 ha)

Other Information

Project contacts:

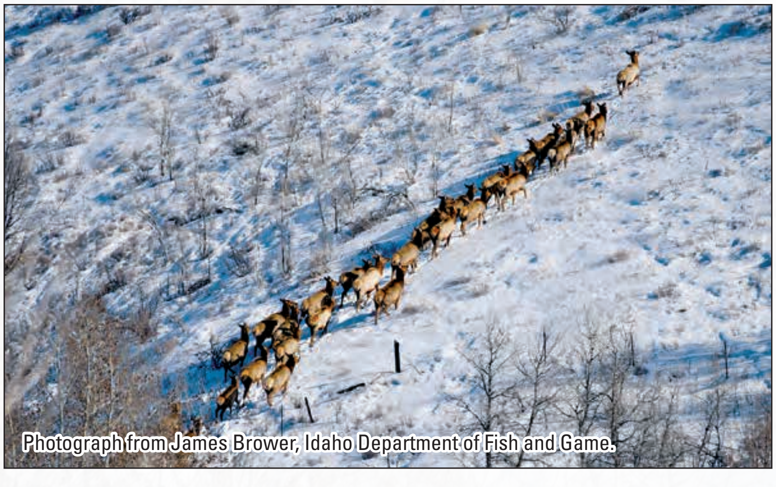
- Mark Hurley (mark.hurley@idfg.idaho.gov), Wildlife Research Supervisor, Idaho Department of Fish and Game
- Curtis Hendricks (curtis.hendricks@idfg.idaho.gov), Regional Wildlife Manager, Idaho Department of Fish and Game

Data analysts:

- Jodi Berg, Senior Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming
- Scott Bergen, Senior Wildlife Research Biologist, Idaho Department of Fish and Game

Reports and publications:

- Ellstrom, M., Hickey, C., Ward, R., Berkley, R., McDonald, M., Lockyer, Z., Hendricks, C., Painter, G., Roche, E., Elmer, M., and Smith, D., 2019, Mule deer surveys and inventories statewide report 2018 seasons: Boise, Idaho, Idaho Department of Fish and Game, 117 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/Mule%20Deer%20Statewide%20FY2019.pdf.]
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game, 49 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/ID%20F16AF00908%20Statewide%20Wildlife%20Research%20Report%20FY18.pdf.]



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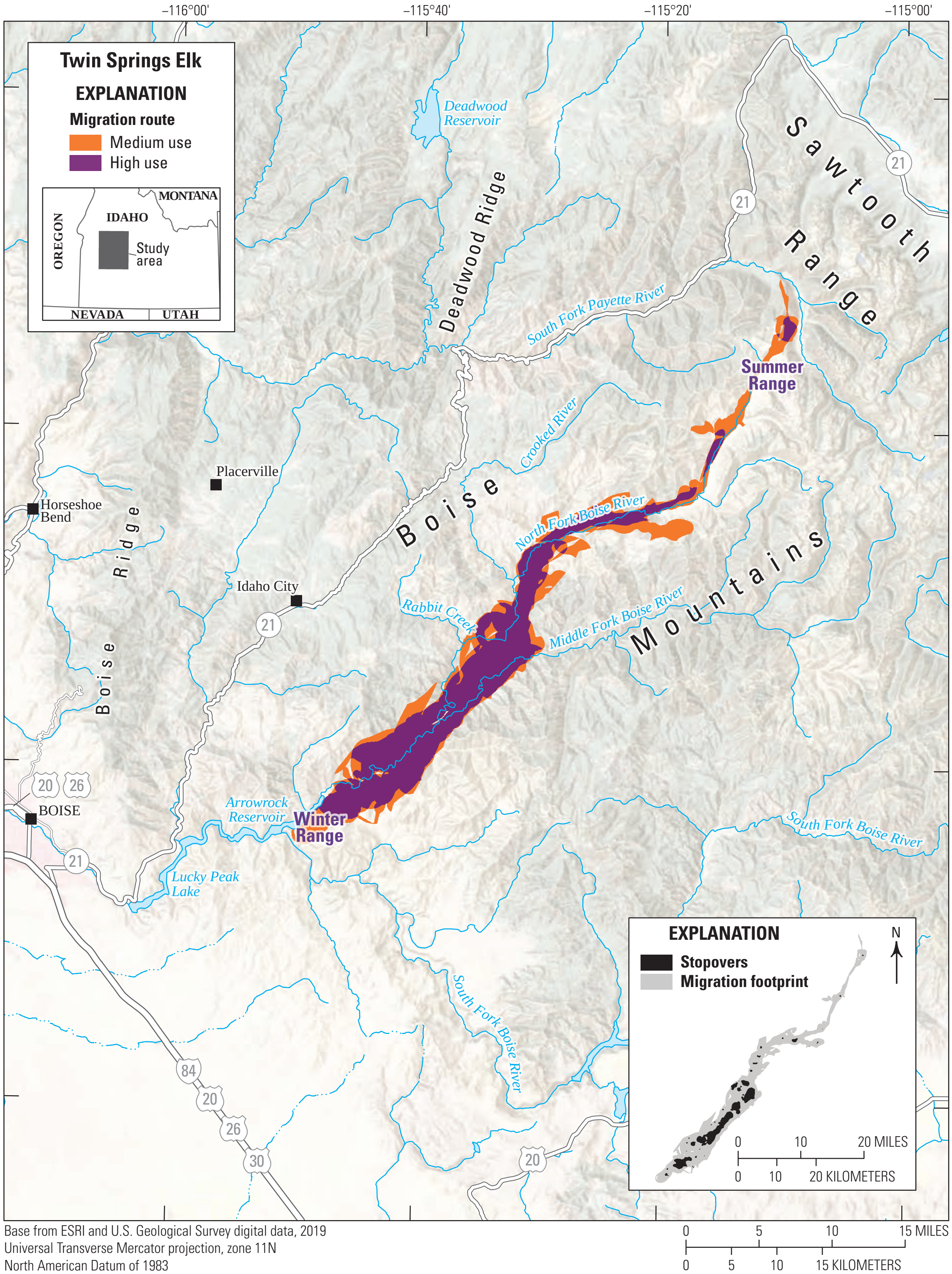


Figure 62. Migration routes and stopovers of the Twin Springs elk herd.

Idaho | Elk

Twin Springs Elk

The Twin Springs elk herd winters between the South Fork Boise River and Arrowrock Reservoir in Idaho (fig. 62). During their spring migrations, these elk typically move through the Boise Mountains and northeast along the North Fork Boise River. Some individuals may travel as far as the South Fork Payette River. On average, the Twin Springs elk herd travels 38 miles to migrate between winter and summer range. The population in the Boise River Elk Zone was estimated to be 8,800 elk in 2021.

Animal Capture and Data Collection

Sample size: 12 female elk
Relocation frequency: 2–23 hours
Project duration: November 2008–January 2020

Data Analysis

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 21 sequences from 12 individuals (9 spring sequences, 12 fall sequences)

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: April 14 to May 8
- Fall: November 5 to December 13

Average number of days migrating:

- Spring: 21 days
- Fall: 31 days

Migration length:

- Minimum: 15.3 mi (24.6 km)
- Mean: 37.9 mi (61.0 km)
- Maximum: 59.1 mi (95.1 km)

Migration area:

- 122,933 acres (49,749 ha) (medium use; 10–20 percent)
- 48,046 acres (19,444 ha) (high use; greater than 20 percent)
- Stopover area: 13,293 acres (5,380 ha)

Other Information

Project contacts:

- Mark Hurley (mark.hurley@idfg.idaho.gov), Wildlife Research Supervisor, Idaho Department of Fish and Game
- Ryan Walrath (ryan.walrath@idfg.idaho.gov), Regional Wildlife Manager, Idaho Department of Fish and Game

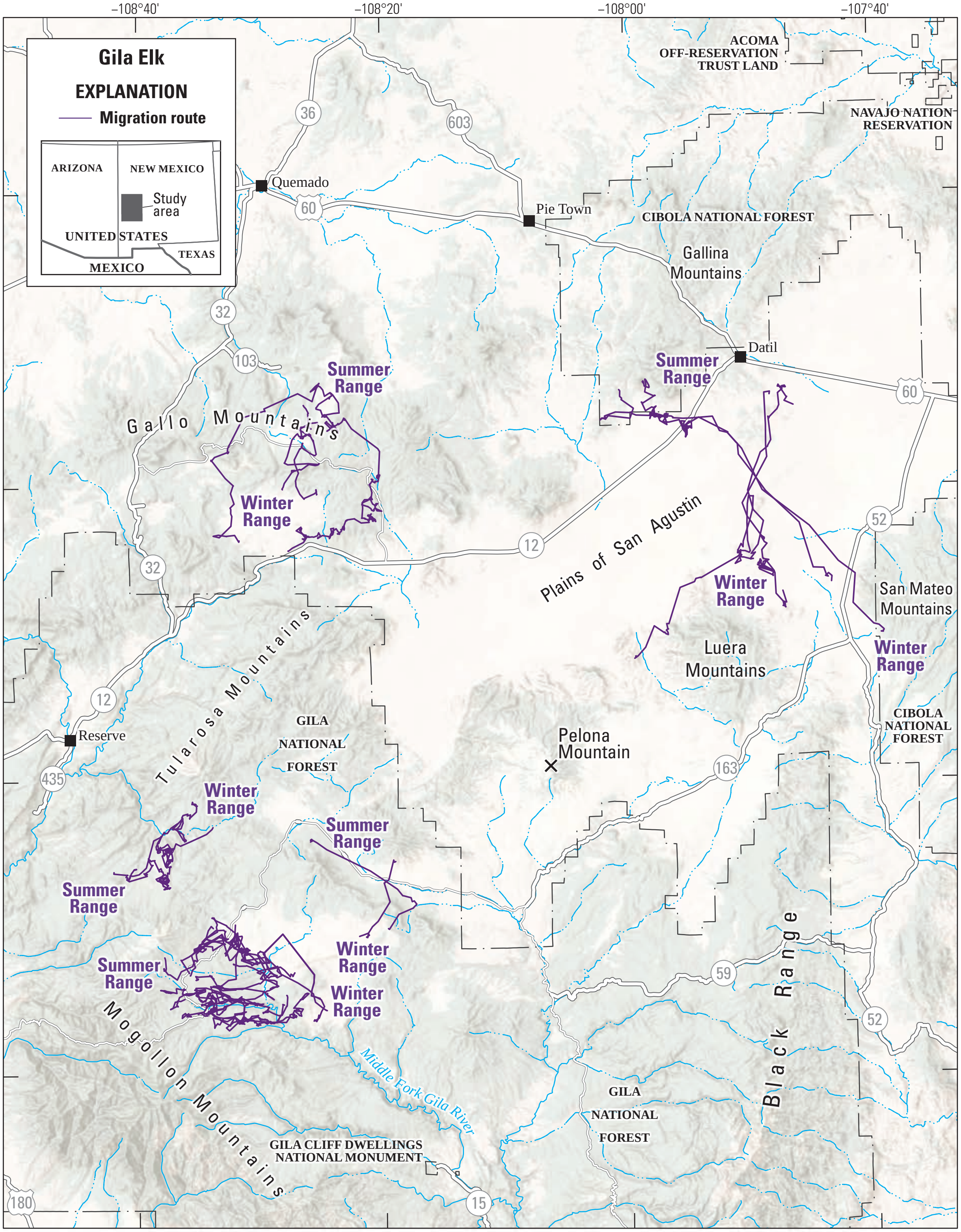
Data analysts:

- Jodi Berg, Senior Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming
- Scott Bergen, Senior Wildlife Research Biologist, Idaho Department of Fish and Game

Reports and publications:

- Ellstrom, M., Hickey, C., Ward, R., Berkley, R., McDonald, M., Lockyer, Z., Hendricks, C., Painter, G., Roche, E., Elmer, M., and Smith, D., 2019, Mule deer surveys and inventories statewide report 2018 seasons: Boise, Idaho, Idaho Department of Fish and Game, 117 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/Mule%20Deer%20Statewide%20FY2019.pdf.]
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game, 49 p. [Also available at https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/ID%20F16AF00908%20Statewide%20Wildlife%20Research%20Report%20FY18.pdf.]

Photograph from Idaho Department of Fish and Game.



Base from ESRI and U.S. Geological Survey digital data, 2019
Universal Transverse Mercator projection, zone 12N
North American Datum of 1983

Figure 63. Migration routes of the Gila elk herd.

New Mexico | Elk

Gila Elk

The Gila elk herd consist of multiple subherds throughout the Gila and Cibola National Forests in western New Mexico (fig. 63). The lower elevations of the Gila National Forest are dominated by various subshrubs, shrubs, and bunch grasses, with the higher elevations consisting primarily of pinyon-juniper woodland, ponderosa pine and mixed conifer forests. The subherds are predominantly nonmigratory, with only approximately 3.4 percent of the 353 collared elk exhibiting migratory behavior, primarily in the Gallo and Mogollon Mountains. Migratory movements may be more common during years of increased snowpack, as the low geographic elevation of the region may mitigate the consequences of remaining at high elevation during winter months in years with low snowpack. Two individuals had longer migrations across the Plains of San Agustin, however their winter and summer ranges were at similar elevations. There are no apparent barriers to migration for this elk herd.

Animal Capture and Data Collection

Sample size: 353 adult female elk
Relocation frequency: 2–4 hours, 6–8 fixes per day
Project duration: 2019–2020

Data Analysis

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 24 sequences from 12 individuals (12 spring sequences, 12 fall sequences)

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: April 5 to April 10
- Fall: November 18 to December 3

Average number of days migrating:

- Spring: 8 days
- Fall: 11 days

Migration corridor length:

- Minimum: 5.1 miles (8.2 km)
- Mean: 11.1 miles (17.9 km)
- Maximum: 27.2 miles (43.7 km)

Winter Range Summary

Winter start and end dates (median):

- December 4 to April 07

Other Information

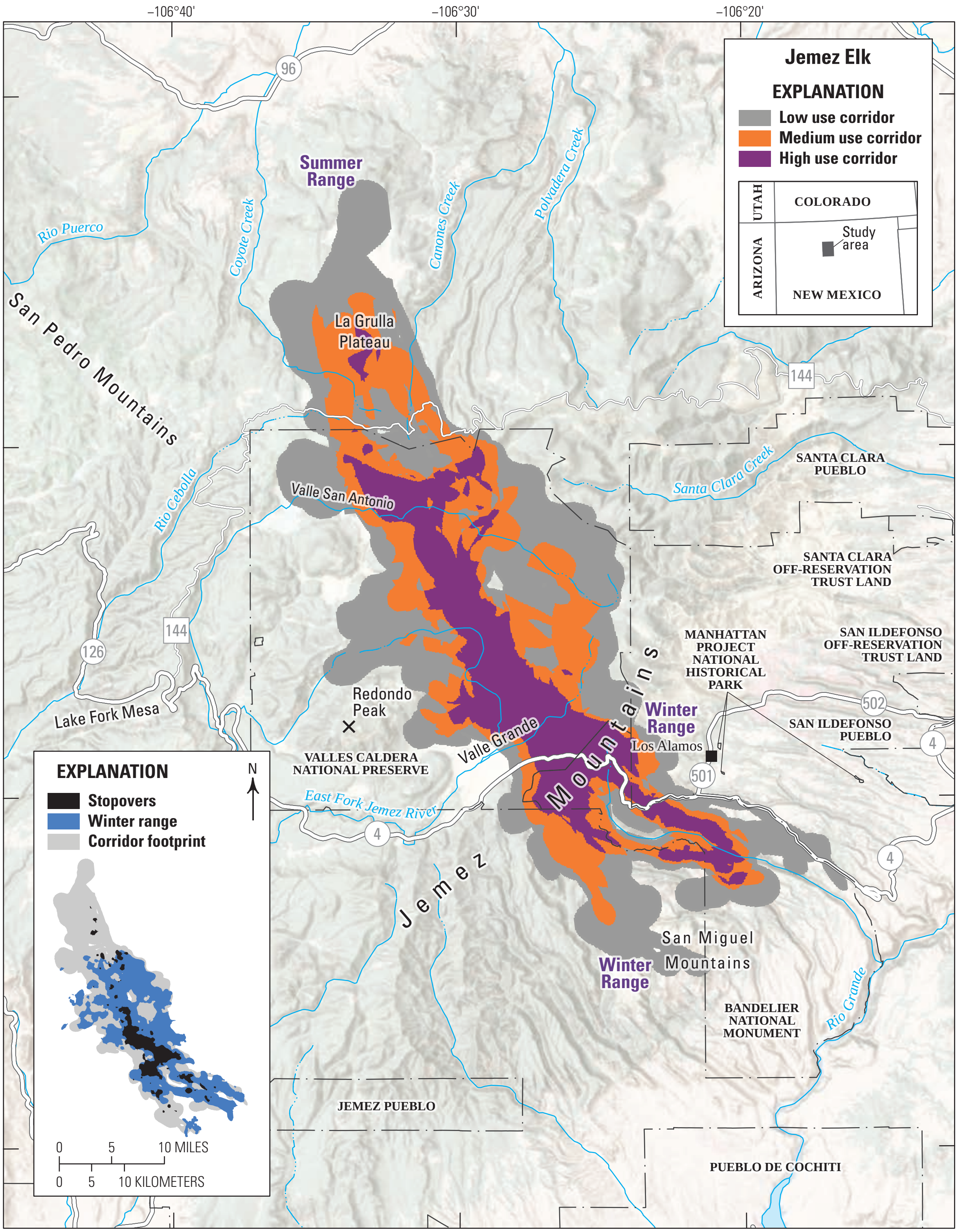
Project contacts:

- James W. Cain (jwcain@nmsu.edu), Assistant Unit Leader, U.S. Geological Survey, New Mexico Cooperative Fish and Wildlife Research Unit, Department of Fish, Wildlife, and Conservation Ecology, New Mexico State University

Data analyst:

- Craig Reddell, GIS Analyst, New Mexico State University

Photograph from Cara Thompson, New Mexico State University.



Base from ESRI and U.S. Geological Survey digital data, 2019
Universal Transverse Mercator projection, zone 13N
North American Datum of 1983

Figure 64. Migration corridors, stopovers, and winter ranges of the Jemez elk herd.

New Mexico | Elk

Jemez Elk

The Jemez elk herd reside primarily in and around the Valles Caldera National Preserve, west of Los Alamos, New Mexico, and along the mesa tops to the north and west of the Valles Caldera (fig. 64). Since 2010, the area experienced two wildfires, the stand replacing Las Conchas fire and the mixed severity Thompson Ridge fire, burning a total of 180,555 acres. The data used in this report were collected to examine the responses of elk to these wildfires and forest restoration treatments. The Jemez elk herd is partially migratory, with residents remaining in the Valles Caldera National Reserve year-round, and migrant individuals traveling to the surrounding lower elevation slopes depending on the year and snowpack levels. The most consistent migration during winter was south towards Bandelier National Monument, while a few individuals migrated east to the Santa Clara Pueblo or west to Lake Fork Mesa. Moreover, while most individuals returned to the Valles Caldera in the early spring, some migrated north to the higher elevations of the La Grulla Plateau. These migrations were relatively short, averaging only 8.7 miles with the longest only reaching 17.5 miles. The Valles Caldera contains a mix of ponderosa pine forests, mixed-conifer forests, and open grasslands, while the lower elevation slopes are predominantly pinyon-juniper woodlands. The primary challenge for individuals migrating would be crossing New Mexico State Route 4 when traveling to Bandelier National Monument.

Animal Capture and Data Collection

Sample size: 80 adult female elk
Relocation frequency: 5–6 hours, 4 fixes per day
Project duration: 2012–2018

Data Analysis

Corridor, stopover, and winter range analysis: Brownian bridge movement models (Sawyer and others, 2009)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 61 sequences from 24 individuals (33 spring sequences, 28 fall sequences)
- Winter: 23 sequences from 16 individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: March 4 to March 15
- Fall: December 13 to December 20

Average number of days migrating:

- Spring: 11 days
- Fall: 11 days

Migration corridor length:

- Minimum: 2.3 miles (3.7 km)
- Mean: 8.7 miles (14.0 km)
- Maximum: 17.5 miles (28.1 km)

Migration corridor area:

- 95,998 acres (38,849.0 ha) (low use; 10 percent)
- 48,951 acres (19,809.7 ha) (medium use; 10–20 percent)
- 21,671 acres (8,769.9 ha) (high use; greater than 20 percent)
- Stopover area: 9,686 acres (3,919.8 ha)

Winter Range Summary

Winter start and end dates (median):

- December 28 to March 5
- Winter length (mean): 114 days
- Winter range (50 percent contour) area: 52,830 acres (21,379.5 ha)

Other Information

Project contacts:

- James W. Cain (jwcain@nmsu.edu), Assistant Unit Leader, U.S. Geological Survey, New Mexico Cooperative Fish and Wildlife Research Unit, Department of Fish, Wildlife, and Conservation Ecology, New Mexico State University

Data analyst:

- Craig Reddell, GIS Analyst, New Mexico State University

Photograph from New Mexico State University.

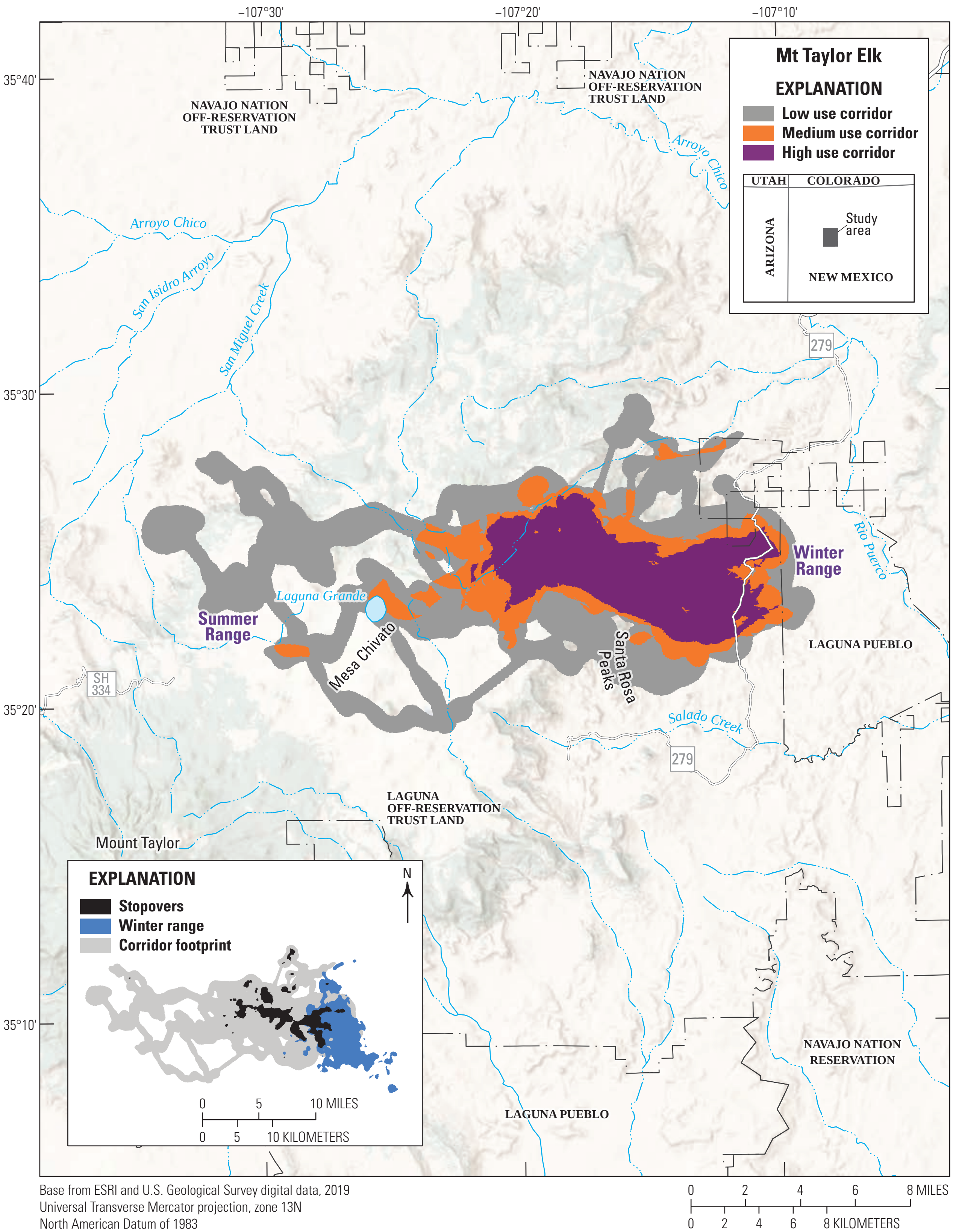


Figure 65. Migration corridors, stopovers, and winter ranges of the Mt. Taylor elk herd.

New Mexico | Elk

Mt. Taylor Elk

The Mt. Taylor elk herd migrate from the northeastern foothills to the northern plateau of Mount Taylor in New Mexico (fig. 65). The data used in this report were collected as part of a larger project examining reasons for sustained low elk calf survival. While the average migration route was 8.2 miles, most of this travel occurred once individuals were on the northern plateau. The distance from winter to summer range was relatively short with individuals climbing approximately 1,500 to 2,000 feet in just more than 2 miles north of the Santa Rosa Peaks. Most elk spent only a short period, less than 30 days, on the winter range, but a few remained for an extended period of up to 201 days. The winter range land cover was primarily mixed salt desert scrub and semidesert grassland, while the summer range was dominated by oak (*Quercus* spp.), pinyon-juniper woodland, and ponderosa pine forests with interspersed grassland openings. The Mt. Taylor elk herd likely does not have major landscape challenges interfering with their ability to migrate, because they move across public lands and several large private ranches.

Animal Capture and Data Collection

Sample size: 29 adult female elk

Relocation frequency: approximately 5 hours, 4 fixes per day

Project duration: 2016–2018

Data Analysis

Corridor, stopover, and winter range analysis: Brownian bridge movement models (Sawyer and others, 2009)

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 65 sequences from 26 individuals (42 spring sequences, 23 fall sequences)
- Winter: 16 sequences from 12 individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: February 21 to March 5
- Fall: January 8 to January 11

Average number of days migrating:

- Spring: 11 days
- Fall: 9 days

Migration corridor length:

- Minimum: 4.1 miles (6.6 km)
- Mean: 8.2 miles (13.2 km)
- Maximum: 19.0 miles (30.5 km)

Migration corridor area:

- 82,951 acres (33,569.1 ha) (low use, less than or equal to10 percent)
- 33,309 acres (13,479.7 ha) (medium use, 10–20 percent)
- 19,471 acres (7,879.6 ha) (high use, greater than 20 percent)
- Stopover area: 8,426 acres (3,409.9 ha)

Winter Range Summary

Winter start and end dates (median):

- January 11 to February 23
- Winter length (mean): 62 days
- Winter range (50 percent contour) area: 19,175 acres (7,759.8 ha)

Other Information

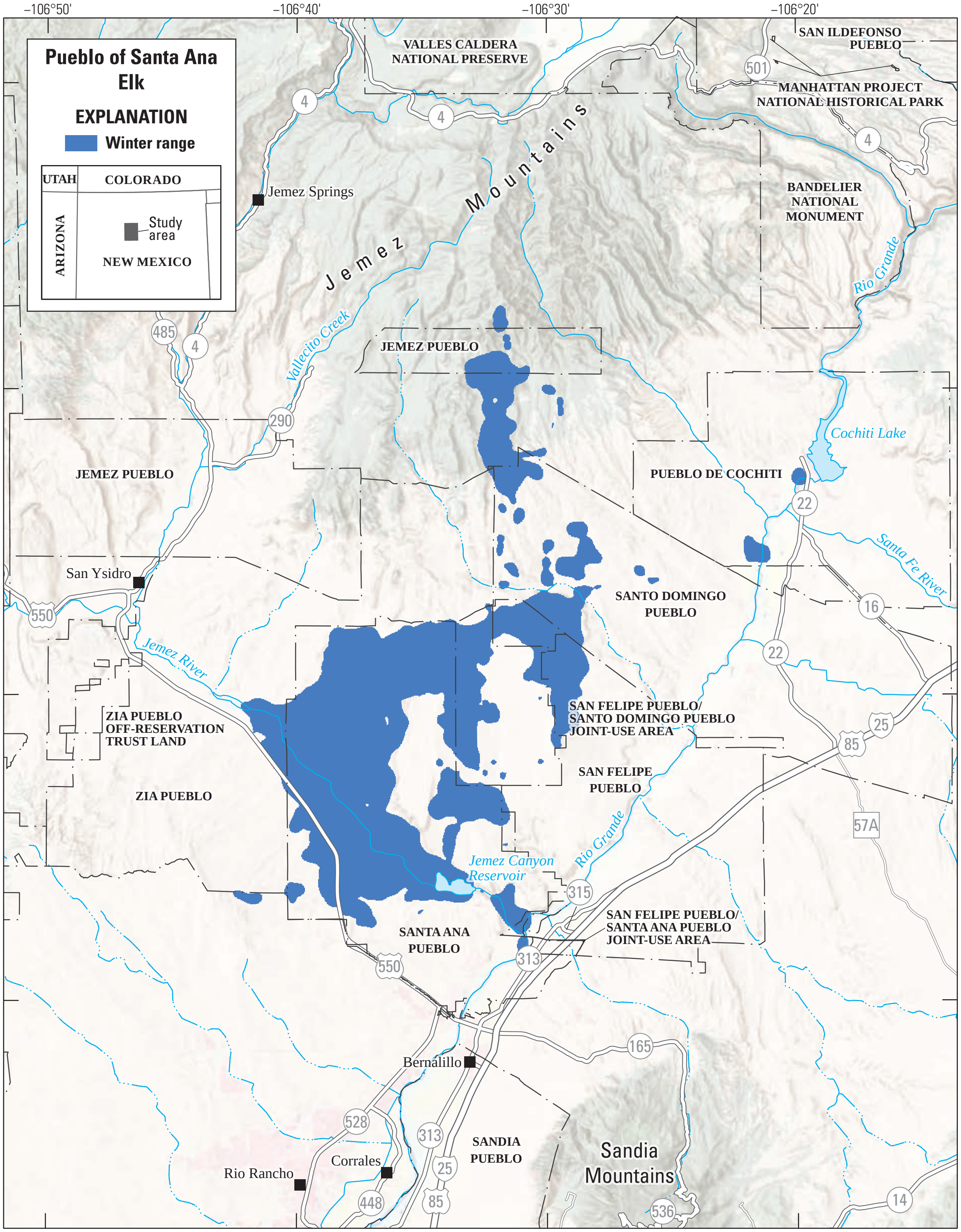
Project contacts:

- Nicole Tatman (Nicole.Tatman@state.nm.us), Big Game Program Manager, New Mexico Department of Game and Fish
- Travis Zaffarano (Travis.Zaffarano@state.nm.us), Elk Program Manager, New Mexico Department of Game and Fish
- Orrin Duvuvuei (Orrin.Duvuvuei@state.nm.us), Deer Program Manager, New Mexico Department of Game and Fish

Data analyst:

- Craig Reddell, GIS Analyst, New Mexico State University

Photograph from Orrin Duvuvuei, New Mexico Department of Game and Fish.



Base from ESRI and U.S. Geological Survey digital data, 2019
Universal Transverse Mercator projection, zone 13N
North American Datum of 1983

0 2 4 6 8 10 MILES
0 2 4 6 8 10 KILOMETERS

Figure 66. Winter ranges of the Pueblo of Santa Ana elk herd.

New Mexico | Elk

Pueblo of Santa Ana Elk

The Pueblo of Santa Ana elk herd are primarily nonmigratory and located northeast of U.S. Route 550 and south of the Jemez Mountains in New Mexico (fig. 66). The winter range is dominated by *Bouteloua eriopoda* (black grama), *Pleuraphis jamesii* (galleta), *Sporobolus flexuosus* (mesa dropseed), and *Atriplex canescens* (fourwing saltbush), with *Pinus ponderosa* (pinyon-juniper woodlands and ponderosa pine) forests dominating the higher elevation slopes of the Jemez Mountains. Two individuals exhibited migratory movements from the lower elevation winter range on the Pueblo of Santa Ana to the higher-elevation slopes of the Jemez Mountains. Challenges to elk movement include the winter range bounded by Interstate 25 to the southeast and U.S. Route 550 to the southwest with elk only crossing U.S. Route 550 west of the Jemez Canyon Reservoir.

Animal Capture and Data Collection

Sample size: 9 adult elk (4 males, 5 females)

Relocation frequency: approximately 4 hours, 6 fixes per day

Project duration: 2010–2017

Data Analysis

Winter range analysis: Brownian bridge movement models (Sawyer and others, 2009)

Delineation of migration periods: December to March (winter range)

Models derived from:

- Winter: 28,068 locations from 9 individuals

Winter Range Summary

Winter start and end dates:

- December 1 to March 1
- Winter length: 90 days
- Winter range (50 percent contour) area: 57,884 acres (23,425 ha)

Other Information

Project contacts:

- Glenn Harper (glenn.harper@santaana-nsn.gov), Range and Wildlife Division Manager, Pueblo of Santa Ana Department of Natural Resources

Data analyst:

- Hall Sawyer, Wildlife Biologist WEST, Inc.

Photograph from Catherine Nishida, Pueblo of Santa Ana.

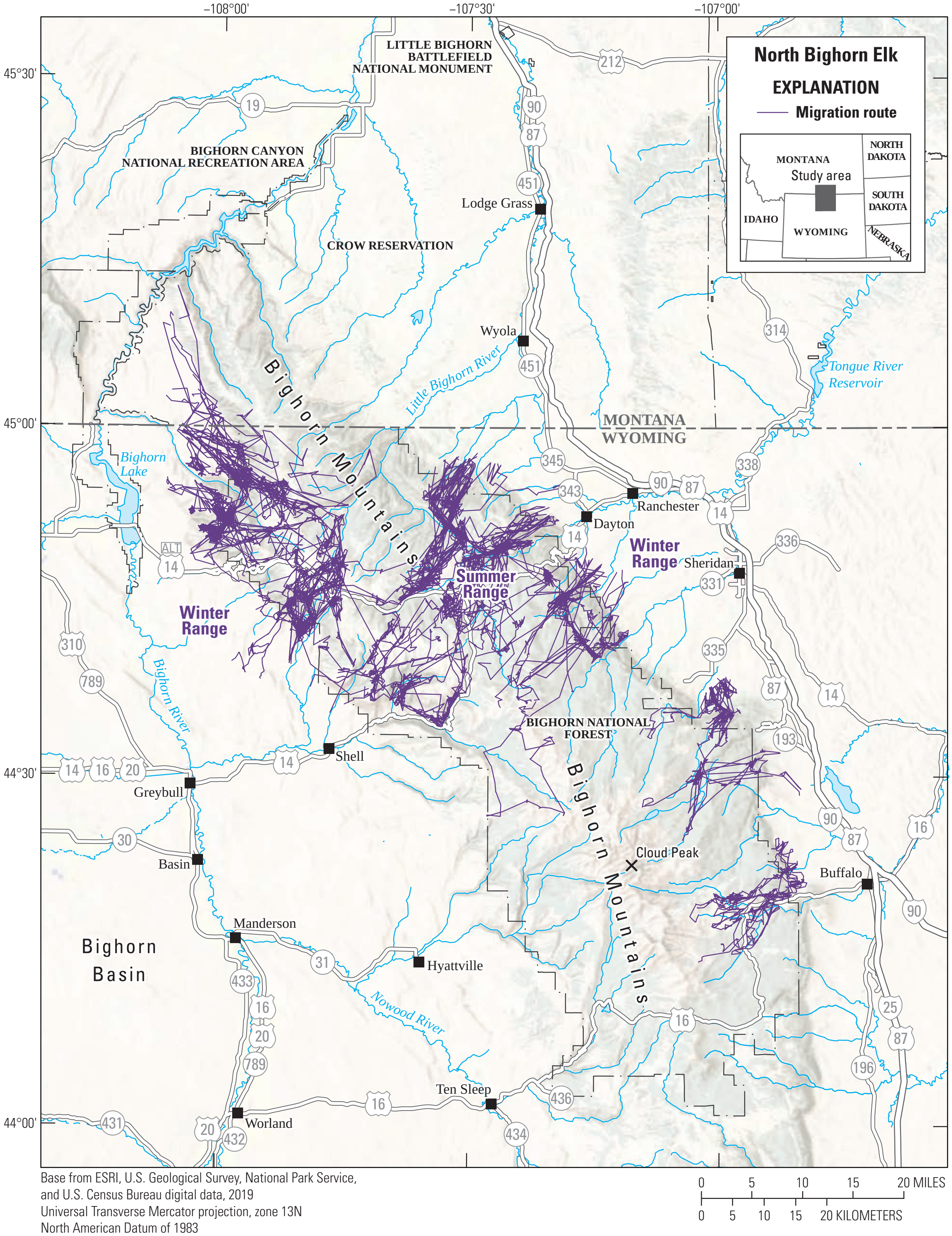


Figure 67. Migration routes of the North Bighorn elk herd.

Wyoming | Elk

North Bighorn Elk

The North Bighorn elk herd within the northern section of the Bighorn Mountains in Wyoming display altitudinal migration. In the spring, the herd migrates from the eastern foothills into the mountains, and in the fall heads back to lower elevations (fig. 67). The herd, which is around 5,500, primarily winters along the eastern foothills of the northern Bighorn Mountains just west of Sheridan, though some will winter north towards Bighorn Canyon National Recreation Area. Winter ranges are a mix of shrubs and herbaceous grasslands, largely supported by private land. During migration animals travel an average one-way distance of 21 mi (34 km) ranging from 5 mi (8 km) to 83 mi (134 km). In spring, animals migrate off winter range westward to the eastern side of the Bighorn Mountains. They traverse the slopes generally following clearings between extensive pine forests. Summer ranges consist of evergreen forests, predominantly lodgepole pine with smaller areas of open herbaceous grasslands. The summer range is almost entirely within the Bighorn National Forest. The population size of the herd remained relatively steady during the early 2000s. While there is a higher concern for the animals on their winter range largely on private land, their migration routes are much safer because they are relatively short, do not cross any highways, and are for the most part within the Bighorn National Forest.

Animal Capture and Data Collection

Sample size: 63 adult female elk
Relocation frequency: 3 hours
Project duration: 2016–2020

Data Analysis

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 109 sequences from 63 individuals (62 spring sequences, 47 fall sequences)
- Winter: 112 sequences from 63 individuals

Route Summary

Migration start and end dates (median):

- Spring: May 19 to June 3
- Fall: September 29 to October 5

Average number of days migrating:

- Spring: 16 days
- Fall: 15 days

Migration route length:

- Minimum: 5.4 mi (8.7 km)
- Mean: 21.4 mi (34.4 km)
- Maximum: 82.7 mi (133.1 km)

Winter Range Summary

Winter start and end dates (median):

- February 5 to May 2
- Winter length (mean): 94 days

Other Information

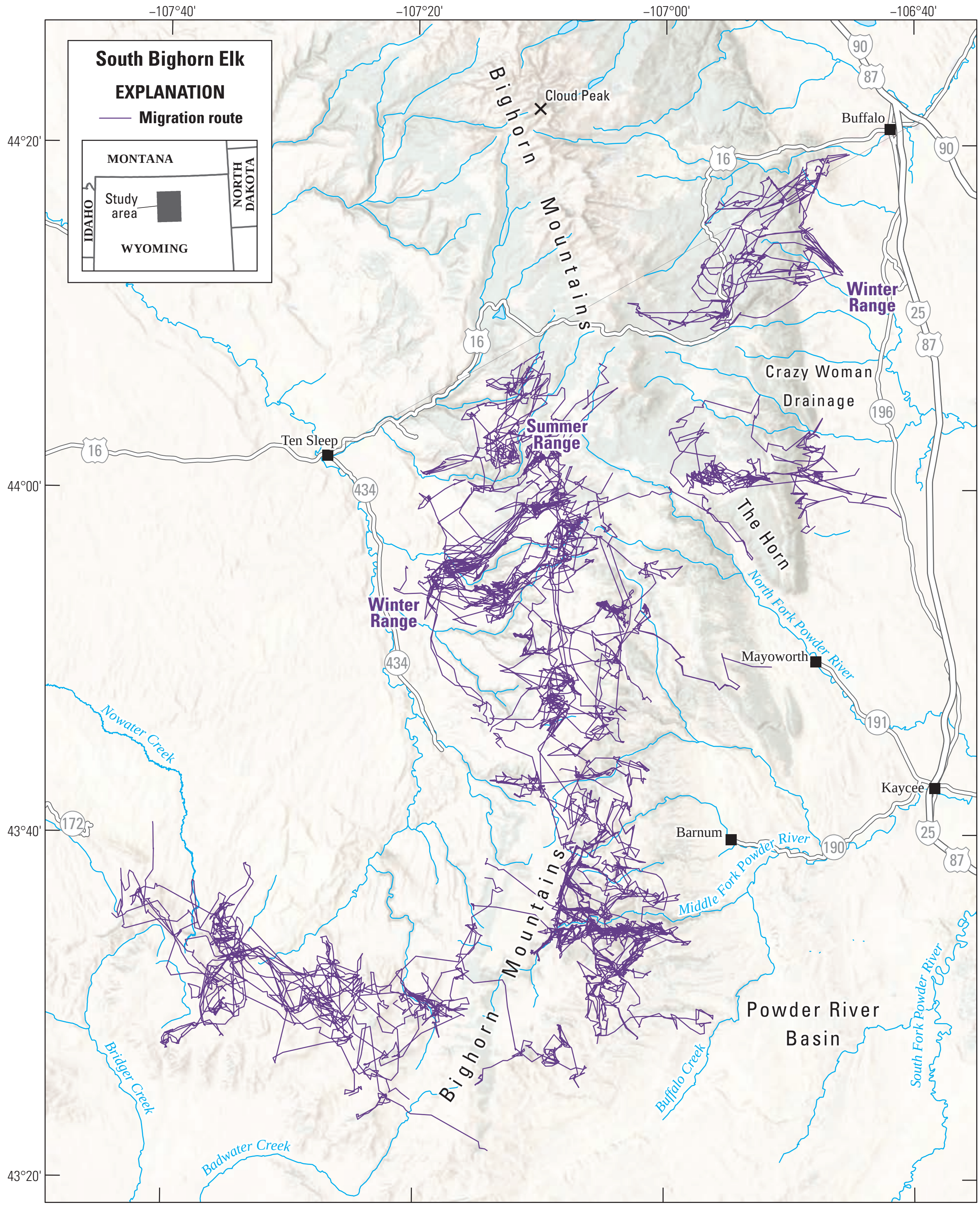
Project contacts:

- Eric Maichak (eric.maichak@wyo.gov), Disease Biologist, Wyoming Game and Fish Department

Data analyst:

- Julien Fattebert, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology

Photograph from Mark Gocke, Wyoming Game and Fish Department.



Base from ESRI, U.S. Geological Survey, National Park Service, and U.S. Census Bureau digital data, 2019
Universal Transverse Mercator projection, zone 13N
North American Datum of 1983

Figure 68. Migration routes of the South Bighorn elk herd.

Wyoming | Elk

South Bighorn Elk

The South Bighorn elk herd within the southern section of the Bighorn Mountains in Wyoming display altitudinal migration. In the spring, most individuals migrate from the western foothills into the mountains, and in the fall, they head back to lower elevations (fig. 68). In the southern section where the range curves west, the herd migrates to the northern foothills in the spring and back in the fall. Additionally, a few individuals summer on the eastern foothills along the Crazy Woman Creek drainage. These individuals migrate the slopes westward in the spring and back in the fall. The approximately 4,000 South Bighorn elk herd primarily winters along the western foothills of the southern Bighorn Mountains, just east of Wyoming Highway 434 (Upper Nowood Road), though some will winter east towards Buffalo, Wyoming. Winter ranges consist primarily of low growing shrubs with smaller areas of herbaceous grasslands, largely supported by private land with scattered areas of BLM land. During migration, animals travel an average one-way distance of 24 mi (39 km), ranging from 10 mi (16 km) to 62 mi (100 km). In the spring, animals migrate off winter range and head east or south to the western or northern side of the Bighorn Mountains. Summer ranges consist of shrub land with smaller areas of evergreen forests. The summer range is a mix of private land and BLM land, though the northern most individuals summer predominantly within the boundaries of the Bighorn National Forest. The population size of the herd has remained relatively steady since the early 2000s. There is a concern for the animals on both their winter and summer ranges, because they largely occupy private land. Similarly, while their migration routes are relatively short, and do not cross any highways, there is still a concern because of the large extent of private land along the route.

Animal Capture and Data Collection

Sample size: 37 adult female elk
Relocation frequency: 3 hours
Project duration: 2017–2020

Data Analysis

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 89 sequences from 33 individuals (50 spring sequences, 39 fall sequences)
- Winter: 84 sequences from 37 individuals

Route Summary

Migration start and end dates (median):

- Spring: April 29 to May 11
- Fall: November 3 to November 6

Average number of days migrating:

- Spring: 16 days
- Fall: 12 days

Migration route length:

- Minimum: 9.9 mi (15.9 km)
- Mean: 24.1 mi (38.8 km)
- Maximum: 61.5 mi (99.0 km)

Winter Range Summary

Winter start and end dates (median):

- December 29 to March 20
- Winter length (mean): 64 days

Other Information

Project contacts:

- Eric Maichak (eric.maichak@wyo.gov), Disease Biologist, Wyoming Game and Fish Department

Data analyst:

- Julien Fattebert, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming

Photograph from Mark Gocke, Wyoming Game and Fish Department.

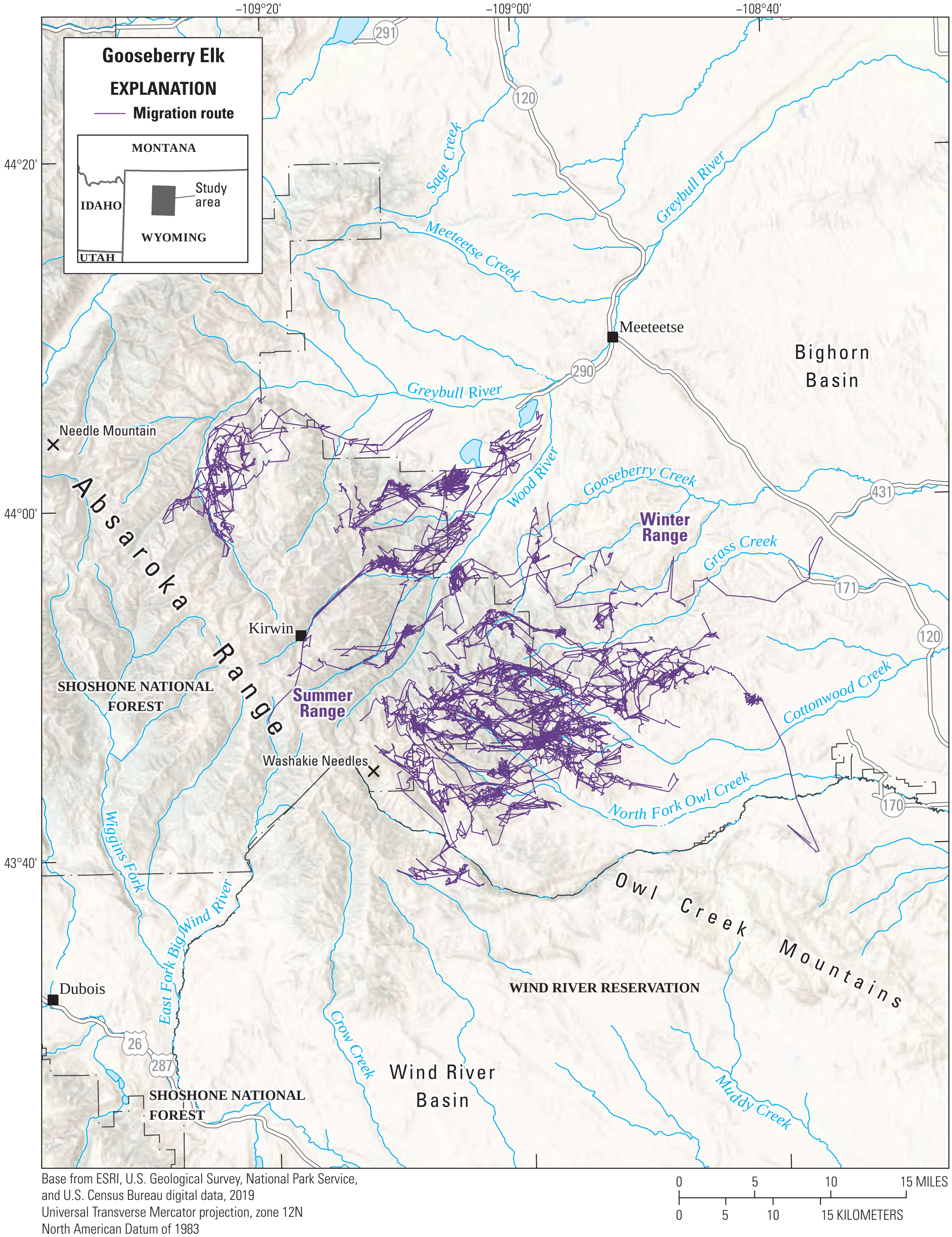


Figure 69. Migration routes of the Gooseberry elk herd.

Wyoming | Elk

Gooseberry Elk

The Goosberry elk herd within the southern section of the Absaroka Range in Wyoming display altitudinal migration. In the spring, they migrate from the eastern foothills into the mountains, and in the fall, they head to lower elevations (fig. 69). The herd, population around 2,700, primarily winters along the southeastern foothills of the Absaroka Range just northwest of the Owl Creek Mountains. Winter ranges consist mostly of shrubs largely supported by private land with smaller areas of BLM land. During migration animals travel an average one-way distance of 22 mi (35 km) ranging from as little as 9 mi (14 km) to as far as 52 mi (84 km). In spring, animals migrate off winter range to the eastern side of the Absaroka Range. Summer ranges consist of evergreen forests predominantly lodgepole pine with smaller areas of open herbaceous grasslands and low growing shrubs. The summer range is almost entirely within the Shoshone National Forest, although some individuals summer within the Wind River Indian Reservation. The population size remained relatively steady since the early 2000s. While there is a higher concern for the animals on their winter range largely on private land, their migration routes are much safer because they do not cross any highways and are for the most part within the Shoshone National Forest. Aside for the few individuals summering in the Wind River Indian Reservation, most of the herd summers within the boundaries of the Shoshone National Forest and is under much less threat during those months.

Animal Capture and Data Collection

Sample size: 41 adult female elk
Relocation frequency: 3 hours
Project duration: 2017–2020

Data Analysis

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 67 sequences from 35 individuals (38 spring sequences, 29 fall sequences)
- Winter: 76 sequences from 41 individuals

Route Summary

Migration start and end dates (median):

- Spring: June 4 to July 8
- Fall: October 1 to October 12

Average number of days migrating:

- Spring: 23 days
- Fall: 22 days

Migration route length:

- Minimum: 3.0 mi (15.0 km)
- Mean: 21.8 mi (35.1 km)
- Maximum: 52.4 mi (84.3 km)

Winter Range Summary

Winter start and end dates (median):

- February 7 to April 30
- Winter length (mean): 102 days

Other Information

Project contacts:

- Eric Maichak (eric.maichak@wyo.gov), Disease Biologist, Wyoming Game and Fish Department

Data analyst:

- Julien Fattebert, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming

Photograph from Mark Gocke, Wyoming Game and Fish Department.

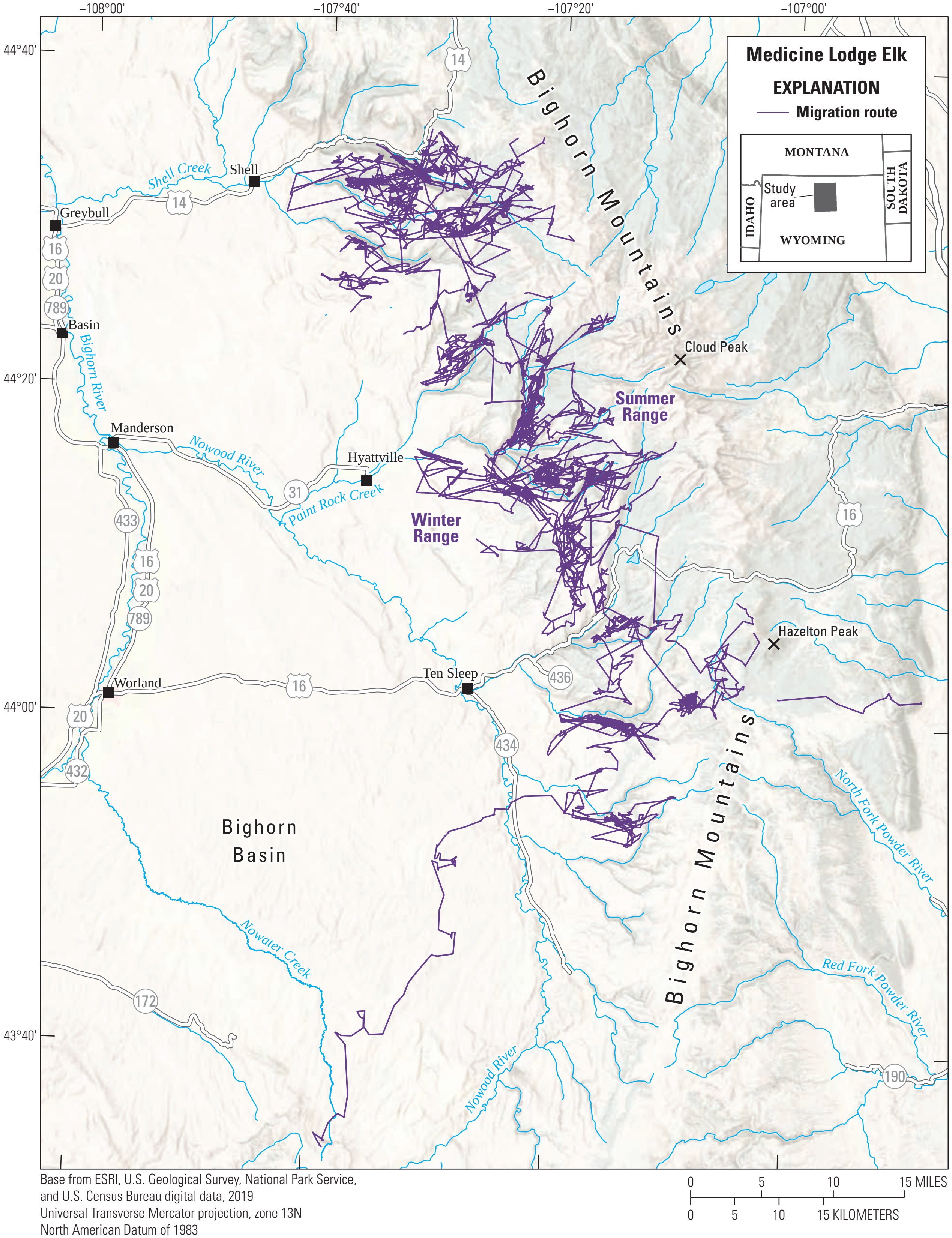


Figure 70. Migration routes of the Medicine Lodge elk herd.

Wyoming | Elk

Medicine Lodge Elk

The Medicine Lodge elk herd within the western section of the Bighorn Mountains in Wyoming display altitudinal migration. In the spring, they migrate from the western foothills into the mountains, and in the fall, they come back to lower elevations (fig. 70). The 2,700 herd winters along the western foothills of the Bighorn Mountains along the eastern section of the Bighorn Basin. Winter ranges are a mix of shrubs and herbaceous grasslands, largely supported by private and BLM land, though many individuals will remain within the boundaries of the Bighorn National Forest. During migration, animals travel an average one-way distance of 20 mi (32 km) ranging from 5 mi (8 km) to 74 mi (119 km). In spring, animals migrate off winter range and head east to the Bighorn Mountains. They traverse the slopes generally following clearings in between extensive pine forests. Summer ranges consist of evergreen forests predominantly lodgepole pine with smaller areas of open herbaceous grasslands. The summer range is almost entirely within the Bighorn National Forest, but some individuals will summer on private land to the south. The population of the herd has remained relatively steady during the last decade. While there is a higher concern for the animals on their winter range containing large areas of private land, their migration routes are much safer because they are relatively short, do not cross any highways, and are for the most part within the Bighorn National Forest.

Animal Capture and Data Collection

Sample size: 26 adult female elk
Relocation frequency: 3 hours
Project duration: 2016–2020

Data Analysis

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 52 sequences from 19 individuals (28 spring sequences, 24 fall sequences)
- Winter: 50 sequences from 26 individuals

Route Summary

Migration start and end dates (median):

- Spring: May 22 to June 4
- Fall: September 29 to October 10

Average number of days migrating:

- Spring: 17 days
- Fall: 14 days

Migration route length:

- Minimum: 4.8 mi (7.7 km)
- Mean: 20.4 mi (32.8 km)
- Maximum: 74.4 mi (119.7 km)

Winter Range Summary

Winter start and end dates (median):

- February 5 to April 26
- Winter length (mean): 102 days

Other Information

Project contacts:

- Eric Maichak (eric.maichak@wyo.gov), Disease Biologist, Wyoming Game and Fish Department

Data analyst:

- Julien Fattebert, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming

Photograph from Mark Gocke, Wyoming Game and Fish Department.

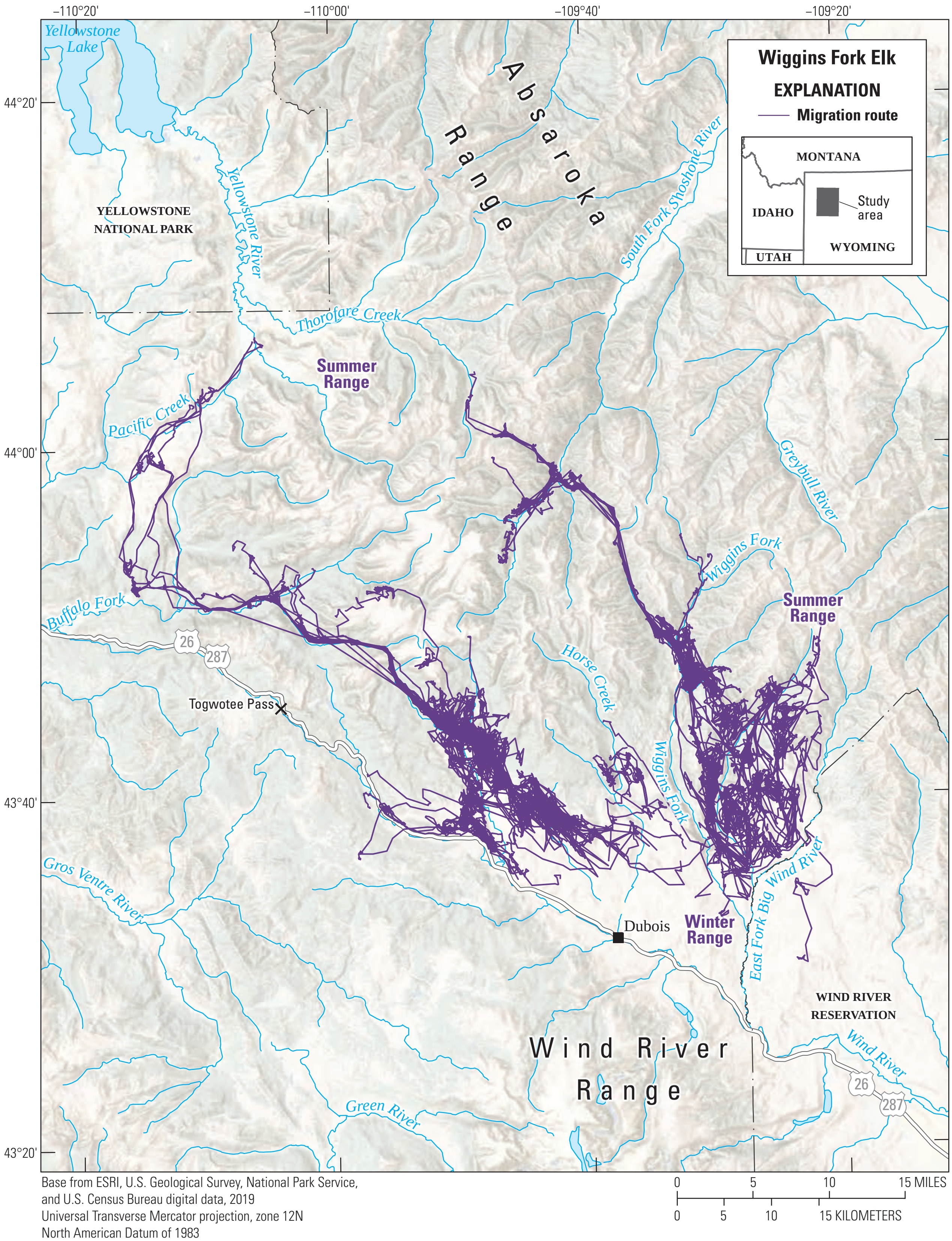


Figure 71. Migration routes of the Wiggins Fork elk herd.

Wyoming | Elk

Wiggins Fork Elk

The Wiggins Fork elk herd within the southernmost section of the Absaroka Range, just north of the Wind River Range in Wyoming, display altitudinal migration (fig. 71). In the spring, they migrate from the southern foothills near Dubois into the mountains, and in the fall, they migrate back to lower elevations. The around 6,000 elk herd primarily winters between the Absaroka Range to the north and the Wind River Range to the south. Winter ranges consist mostly of shrubs, largely supported by private land with smaller areas of BLM and Wyoming Game and Fish land. During migration animals travel an average one way distance of 32 mi (51 km), ranging from 8 mi (13 km) to 69 mi (111 km). In spring, animals migrate off winter range and head north and northwest to the southern side of the Absaroka Range following clearings between the pine trees. Summer ranges consist of evergreen forests, predominantly lodgepole pine with smaller areas of open herbaceous grasslands and low growing shrubs. The summer range is almost entirely within the Shoshone National Forest; however, a large portion of the Wiggins Fork herd group off and head northwest into the Bridger-Teton National Forest. The population of the herd has remained relatively steady during the last decade. While there is a higher concern for the animals on their largely private land winter range, their migration routes are much safer, because they do not cross any highways and are for the most part within the Shoshone or Bridger-Teton National Forests. The group that migrates northwest into the Absaroka Range may encounter U.S. Highway 26, which could pose a threat of collision with motorists. Additionally, some individuals may winter in the Wind River Indian Reservation. Most of the herd summers within the boundaries of the Shoshone and Bridger-Teton National Forest and are under much less threat during those months.

Animal Capture and Data Collection

Sample size: 16 adult female elk
Relocation frequency: 2 hours
Project duration: 2015–2018

Data Analysis

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)

Models derived from:

- Migration: 80 sequences from 16 individuals (42 spring sequences, 38 fall sequences)
- Winter: 59 sequences from 16 individuals

Route Summary

Migration start and end dates (median):

- Spring: May 13 to May 29
- Fall: November 11 to November 27

Average number of days migrating:

- Spring: 18 days
- Fall: 26 days

Migration route length:

- Minimum: 7.7 mi (12.4 km)
- Mean: 31.7 mi (51.0 km)
- Maximum: 66.8 mi (107.5 km)

Winter Range Summary

Winter start and end dates (median):

- December 18 to April 15
- Winter length (mean): 100 days

Other Information

Project contacts:

- Arthur Middleton (amiddleton@berkeley.edu), Department of Environmental Science, Policy, and Management, University of California Berkeley
- Greg Anderson (gregory.anderson@wyo.gov), Wildlife Biologist, Wyoming Game and Fish Department

Data analyst:

- Julien Fattebert, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming

Photograph from Mark Gocke, Wyoming Game and Fish Department.

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Appendix 1. Methods

Corridors and Stopovers

Extracting and Mapping Migration Sequences

To identify spring and fall migration start and end dates for a given individual in a given year (in other words individual year), we visually inspected the Net Squared Displacement (NSD) curve (Bunnefeld and others, 2011, Bastille-Rousseau and others, 2016) alongside digital maps of the animal's movement trajectory (Merkle and others, 2017). The NSD represents the square of the straight-line distance between any global positioning system location of an animal's movement trajectory and a point within the animal's winter range. Users defined this point separately for each herd based on the start of a biological year, which ranged between January 1 and March 31. When an animal stays within a defined home range, the NSD varies relatively little during the course of a year. However, when an animal migrates away from its winter range, the NSD of each successive location increases until the animal settles in its summer range (fig. 1.1). The days with clear breakpoints in the NSD curves represent the start and end dates for migration and were used to define migration sequences for spring and fall migration. Migration routes were mapped by joining successive GPS locations by a straight line within each migration sequence.

A

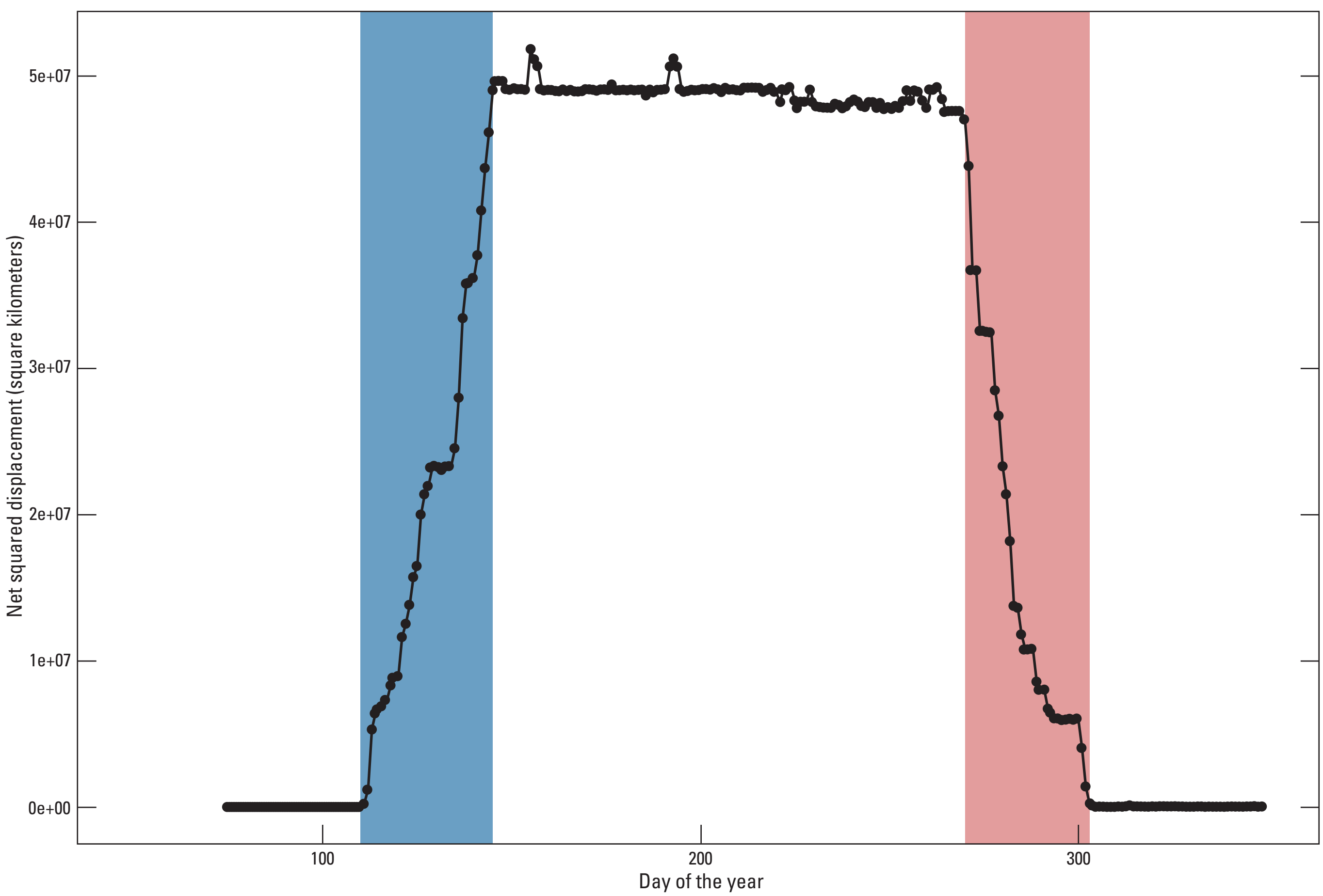
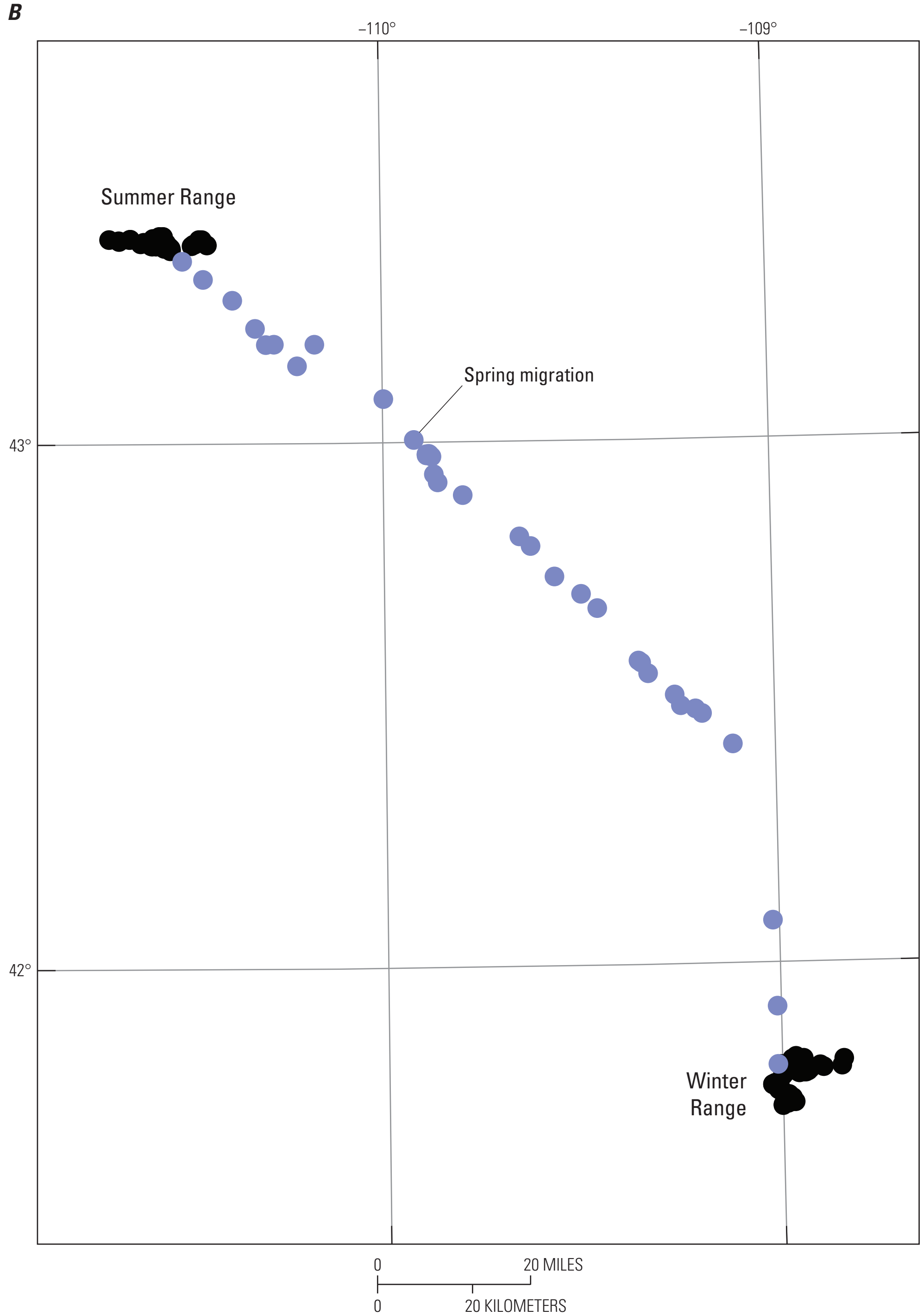


Figure 1.1. Example of Net Squared Displacement (NSD) analysis to identify migration sequences. Breakpoints in the NSD curve provide the start and end dates for the spring migration (blue polygon) when an animal migrates away from winter range to summer range. Fall migration (red polygon) is shown when an animal leaves summer range back to winter range, *A*. The corresponding GPS fixes are highlighted on the map insets for the spring migration in blue, *B;* and the fall migration in red, *C*, respectively. For ease of readability, only one GPS fix per day is shown, in black.

B



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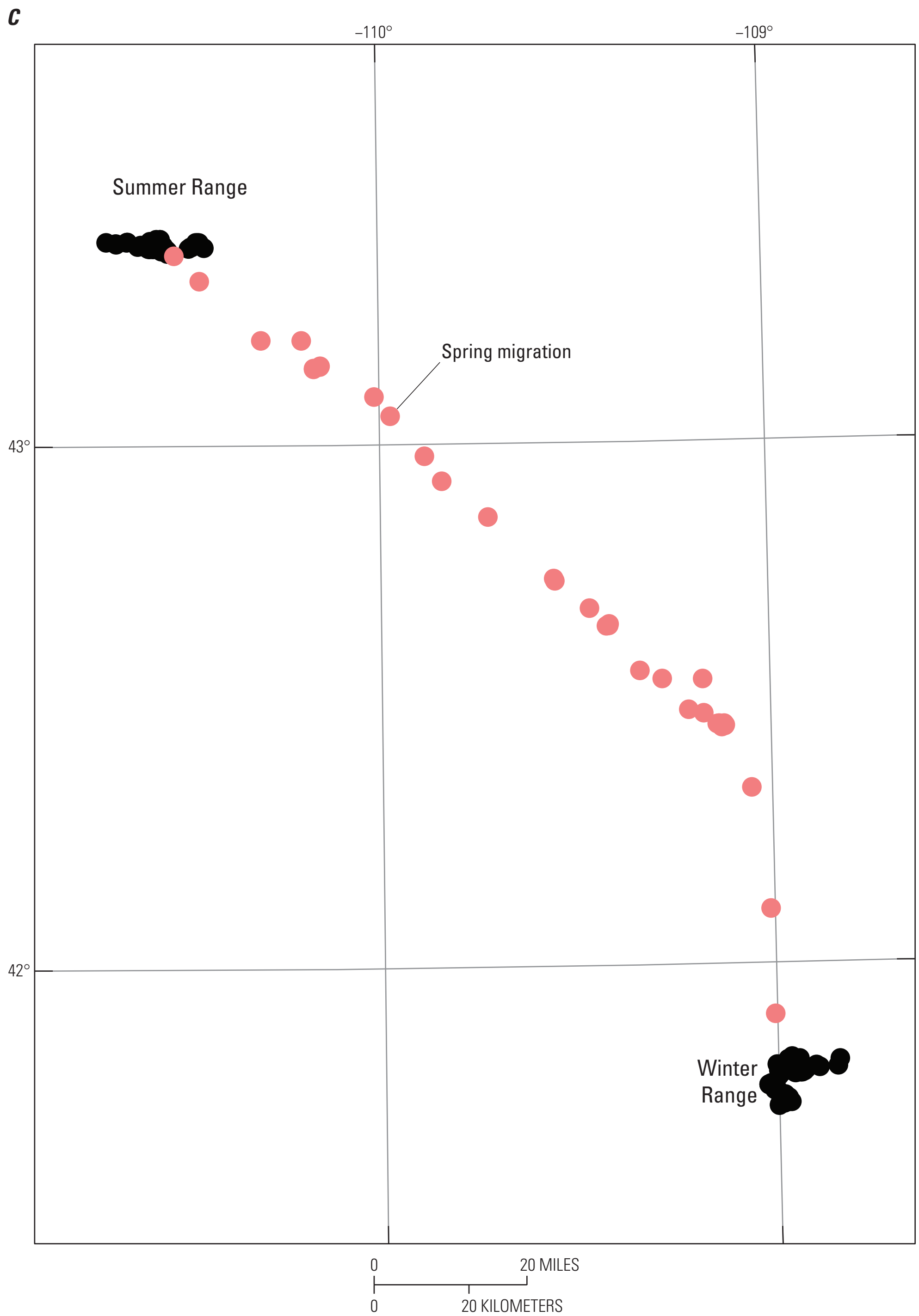

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Calculating Probability of Use with Brownian Bridge Movement Models

Once migration sequences were extracted for each individual year, we used a Brownian bridge movement model (BBMM) (Horne and others, 2007) to estimate an occurrence distribution (in other words, the probability of where the animal could have traveled during its migration, hereafter, utilization distribution [UD]). The UD provides a heat map of use for each migration sequence. The probability surface estimates the possible width of the movement path around the straight line between two successive locations and can be used to identify migration corridors (Sawyer and others, 2009) and the stopover sites where animals spend extended time foraging along their migration route (Sawyer and Kauffman, 2011).

To generate the heat map for each migration sequence, we calculated a BBMM using a grid with 50-meter (164-foot) resolution. When GPS collars missed fixes and there were breaks in the sequential data above an 8-hour time lag, we did not build a bridge between them. A key parameter of the BBMM is the Brownian Motion Variance (BMV), which provides an index of the mobility of the particular animal under observation (Horne and others, 2007). An empirical estimate of the BMV was obtained for each migration sequence following the methods of Horne and others (2007). We did not include migration sequences with a BMV less than or equal to 8,000, because subsequent visualizations of the heat map generated from BBMMs with large BMV values poorly represented the observed migration trajectory.

Variations of the Method—Sparse Data and Fixed Motion Variance

When location data are sparse (in other words, when GPS fixes are not taken often), BBMM performs poorly because of the increased uncertainty in the movement path between two successive GPS locations. Such uncertainty can result in overestimates of the corridor width and area (Horne and others, 2007; Benhamou, 2011). To facilitate corridor analyses of migration sequences collected with low fix rates, we used the alternative Fixed Motion Variance approach, in which we manually fixed the BMV when estimating the UDs for each migration sequence (Kauffman and others, 2020a). For herds with low fix frequency we fixed the BMV between 600 to 1,600 for elk and pronghorn and between 400 to 1,200 for mule deer. Additionally, for pronghorn in Idaho, which have variable winter ranges across the state, we used June 1 (in other words, peak fawning) as the anchor location when measuring NSD and identifying migration start and end dates.

Calculating Population-Level Corridors and Stopovers

We applied a three-step process to calculate population-level corridors and to identify stopovers, which generally followed the methods developed by Sawyer and others (2009). First, we averaged the UDs for a given individual’s spring and fall migration sequences across all years to produce a single, individual-level migration UD. We rescaled this averaged UD to sum to 1. Second, we defined a migration footprint for each individual as the 99 percent isopleth of its UD. We then stacked all the individual footprints for a given population, which provided a raster representing the number of animals that used each grid cell during migration. We then defined different levels of corridor use based on the proportion of the collared animals in the population using a given pixel. Low-use corridors were defined as areas traversed by greater than or equal to 1 individual during migration, medium-use corridors were used by greater than or equal to 10 percent of individuals within the population, and high-use corridors were used by greater than or equal to 20 percent of the migrant individuals within the population. These corridors were converted from a grid-based format to a polygon format, while removing isolated use polygons of less than 20,000 square miles (in other words, less than approximately 5 acres). Finally, for the stopover calculation, instead of calculating footprints from each individual-level UD, we averaged all the individual-level UDs to produce a single population-level UD, rescaled to sum to 1. Stopovers were defined as the areas representing the highest 10 percent of use from population-averaged UD. As with the corridors, we then converted stopovers from a grid-based format to a polygon format and removed isolated polygons of less than 5 acres.

Variations of the Method to Calculate Population-Level Corridors or Routes

Most maps in this report display low-, medium- and high-use corridors or routes. However, some individual states adapted methodologies to best suit their management purposes. For example, in Idaho, low-use was defined as 2 individuals ranging up to 10 percent, and when sample size was less than or equal to 20 individuals, only medium- and high-use migration routes were shown.

In the majority of cases, traditional BBMM methods were used to estimate corridors and stopovers. However, when there were significant amounts of data-acquisition failures in the migration sequences, corridors were calculated using Fixed Motion Variance techniques if they improved delineation as observed through visual comparison of maps from the two methods. When fix rates were highly variable among individuals in a herd both, BBMM and Fixed Motion Variance methods were used to construct individual UDs within a herd. In general, by bridging gaps in the probability surface because of missing GPS locations, using Fixed Motion Variance provided a modeled corridor that more closely matched data with frequent relocations (in other words, 2-hour fix rate). In most of these cases, a 14-hour time lag was allowed. A 27-hour time lag was allowed only when it provided more complete migration corridors compared to using a 14-hour time lag.

Estimating a Population's Winter Range

To estimate a population's winter range, we generally followed the methods for calculating migration stopover sites with some exceptions. First, instead of migration sequences, we isolated winter sequences. These were defined as movements between fall and spring migrations. For each year, we calculated a standard date for the start and end of winter and applied one of two options to calculate winter range dates based on the preference of individual states: (1) for each year, we calculated the start of winter as the 95th percent quantile of the end dates of all fall migrations, and the end of winter as the 5th percent quantile of the start dates of all spring migrations, or (2) we defined a fixed date range based on local expert knowledge for a given herd (for example, December 15 to March 15). We discarded winter sequences that spanned less than 30 days, except for the Mt. Taylor elk herd where we dropped the threshold to 15 days. Following the methods for migration stopovers, we calculated a population-level UD of winter use and identified the core winter range using the 50th percent isopleth.

Estimating a Population's Annual Range

To estimate a population's annual range, we generally followed the methods for calculating migration stopover sites or winter range with some exceptions. First, we isolated annual sequences for each individual. These were defined as movements consisting of greater than 275 days within a calendar year beginning at the time of collar deployment. Start dates were similar because GPS collars were deployed in batches around the same dates. End dates sometimes varied depending on mortalities. Following the methods for migration corridors, we calculated a population-level UD of annual use and identified the core annual range using isopleth values selected based on local expert knowledge for a given herd.

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