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Ungulate Migrations of the Western United States, Volume 1

Scientific Investigations Report 2020–5101
Version 1.1, December 2023

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

Cover. Deer crossing the outlet of Fremont Lake, Wyoming (Photograph by Mark Thonhoff).

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By Matthew Kauffman, Holly Copeland, Jodi Berg, Scott Bergen, Eric Cole, Matthew Cuzzocreo, Sarah Dewey, Julien Fattebert, Jeff Gagnon, Emily Gelzer, Chris Geremia, Tabitha Graves, Kent Hersey, Mark Hurley, Rusty Kaiser, James Meacham, Jerod Merkle, Arthur Middleton, Tristan Nuñez, Brendan Oates, Daniel Olson, Lucas Olson, Hall Sawyer, Cody Schroeder, Scott Sprague, Alethea Steingisser, and Mark Thonhoff

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DAVID BERNHARDT, Secretary

U.S. Geological Survey
James F. Reilly II, Director

U.S. Geological Survey, Reston, Virginia: 2020
Revised: December 2023 (ver 1.1)

Suggested citation:
Kauffman, M.J., Copeland, H.E., Berg, J., Bergen, S., Cole, E., Cuzzocreo, M., Dewey, S., Fattebert, J., Gagnon, Gelzer, E., Geremia, C., Graves, T., Hersey, K., Hurley, M., Kaiser, J., Meacham, J., Merkle, J., Middleton, A., Nuñez, T., Oates, B., Olson, D., Olson, L., Sawyer, H., Schroeder, C., Sprague, S., Steingisser, A., Thonhoff, M., 2020, Ungulate migrations of the western United States, Volume 1 (ver. 1.1, December 2023): U.S. Geological Survey Scientific Investigations Report 2020–5101, 119 p., https://doi.org/10.3133/sir20205101.

Associated data for this publication:
Kauffman, M.J., Copeland, H.E., Cole, E., Cuzzocreo, M., Dewey, S., Fattebert, J., Gagnon, J., Gelzer, E., Graves, T., Hersey, K., Kaiser, R., Meacham, J., Merkle, J., Middleton, A., Nuñez, T., Oates, B., Olson, D., Olson, L., Sawyer, H., Schroeder, C., Sprague, S., Steingisser, A., and Thonhoff, M., 2020, Ungulate migrations of the western United States: U.S. Geological Survey data release, https://doi.org/10.5066/P9O2YM6I.

ISSN 2328-031X (print)
ISSN 2328-0328 (online)

ISBN 978-1-4113-4379-5

Acknowledgments

Over many years, numerous agency biologists, wardens, students, and postdocs have contributed thousands of hours into planning, collecting, and analyzing the data that pertain to each of the herds described in this report. Many staff and students with Infographics Lab at the University of Oregon Department of Geography were involved in map design and production. These included research assistant Joanna Merson, and the following students: Arielle Alfarez, Bernard Cowen, Greg FitzGerald, Jacob Maurer, and Julia Olson. Coordination and administration of this work across U.S. Department of the Interior bureaus and western states was facilitated by Casey Stemler, Tom Remington, Zach Bowen, and John Thompson. At the USGS, Jeff Hartley contributed with cartographic design and production. In Arizona, Sue Boe, Norris Dodd, Jim Heffelfinger, Steve Rosenstock, Ray Schweinsburg provided technical support for this report. In Idaho, the following individuals with Idaho Department of Fish and Game assisted with data collection and coordination: Regan Berkley, Frank Edelmann, Mike Elmer, Curtis Hendricks, Zach Lockyer, Mike McDonald, Dennis Newman, Jessie Shallow, Rick Ward. In Wyoming, the following individuals at the Wyoming Game and Fish Department contributed in data collection, herd descriptions, and information: Greg Anderson, Tom Berdan, Corey Class, Dean Clause, Alyson Courtemanch, Teal Cufaude, Phil Damm, Gary Fralick, Embere Hall, Stan Harter, Neil Hymas, Bart Kroger, Ron Lockwood, Daryl Lutz, Doug McWhirter, Tony Mong, Brandon Scurlock, Sam Stephens, Jeff Short, Will Schultz, Ben Wise, Tim Wooley, and Mark Zornes. Additionally, in Wyoming, the following organizations or individuals assisted with data collection: Arvid Aase, Scott Becker, Carson Butler, Steve Cain, Doug Chapman, Samantha Dwinell, Marcia Fagnant, numerous Grand Teton National Park employees and volunteers, Jenny Jones, Carrie Kyle, Clayton Kyte, Tayler LaSharr, David McGinnis, Nate Mikle, Kevin Monteith, Erik Norelius, Lara Oles, Ed Olexa, Anna Ortega, Liz Parker, Justin Schwabedissen, and Rick Wallen.

Funding for the collaring and collection of ungulate migration data across all states was provided by the following organizations: Anadarko Petroleum Company, Arizona Antelope Foundation, Arizona Deer Association, Arizona Department of Transportation, Arizona Elk Society, Arizona Game and Fish Department (Region II, III, and the Research, Contracts, and Game Branches), Barrick Gold Corporation, Bole and Klingenstein Foundation, The Boone and Crockett Club, Bowhunters of Wyoming, Wyoming Bureau of Land Management Charles Engelhard Foundation, Cross Charitable Foundation, Finley Resources, Inc., Fossil Butte National Monument, George B. Storer Foundation, Grand Teton National Park Foundation, Grand Teton Association, Greater Yellowstone Coordinating Committee, Greater Yellowstone Interagency Brucellosis Committee, Idaho Department of Fish and Game, Kinross Gold, Knobloch Family Foundation, Little Snake River Conservation District, Meg and Bert Raynes Wildlife Fund, Mule Deer Foundation, Southwest Chapter of the Muley Fanatic Foundation, Southeast Chapter of the Muley Fanatic Foundation, 10 Country Chapter of the Muley Fanatic Foundation, Upper Green Chapter of the Muley Fanatic Foundation, Kemmerer Chapter of the Muley Fanatic Foundation, and the Snake River Chapter of the Mule Deer Foundation, National Elk Refuge, National Park Service, National Science Foundation Ecology of Infectious Disease, National Science Foundation Long Term Research in Environmental Biology Grant, The Nature Conservancy, Newmont Mining Corporation, the Nevada Wildlife Heritage Fund, Plains Exploration and Production Company, Questar Exploration and Production, University of Nevada – Reno, University of Wyoming School of Energy Resources, U.S. Fish and Wildlife Service (USFWS), USFWS Wildlife and Sport Fish Restoration Program, U.S. Forest Service (Bridger-Teton and Shoshone National Forests, Southwestern Regional Office), U.S. Geological Survey (USGS)

Wyoming Landscape Conservation Initiative, Ricketts Conservation Foundation, Rocky Mountain Elk Foundation, Safari Club International Foundation (SCIF), SCIF Hunter Legacy 100 Fund, Teton County Conservation District, Wildlife Heritage Foundation of Wyoming, Wyoming Animal Damage Management Board, Wyoming Game and Fish Department, Wyoming Governor's Big Game License Coalition, Wyoming Wildlife Foundation, Wyoming Wildlife and Natural Resource Trust, Wyoming and Sublette County Outfitters and Guides Association.

Funding for the identification of state migration data and coordination on the project with the Western Association of Fish and Wildlife Agencies (WAFWA) was provided by WAFWA's Sagebrush Science Initiative, with funding support from the USFWS. Primary funding for the analysis and compilation of this report came from the USGS Ecosystems Mission Area.

Thanks to James Cain and Blake Lowrey for their time and effort in reviewing this report.

Contents

Figures

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

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

Abbreviations

BBMM	Brownian Bridge Movement Model
BMV	Brownian Motion Variance
DAU	Data Analysis Unit
DOD	U.S. Department of Defense
EPA	U.S. Environmental Protection Agency
FMV	Fixed Motion Variance
GMU	Game Management Unit
GPS	Global Positioning System
NAD 83	North American Datum of 1983
NAVD 88	North American Vertical Datum of 1988
NDVI	Normalized Difference Vegetation Index
NGVD 29	National Geodetic Vertical Datum of 1929
NSD	Net Squared Displacement
PMU	Population Management Unit
ppm	parts per million
UD	utilization distribution
USGS	U.S. Geological Survey
VHF	Very High Frequency
WGFD	Wyoming Game and Fish Department
WYDOT	Wyoming Department of Transportation

Ungulate Migrations of the Western United States, Volume 1

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Abstract

Across the western United States, many ungulate herds must migrate seasonally to access resources and avoid harsh winter conditions. Because these migration paths cover vast landscapes (in other words migration distances up to 150 miles [241 kilometers]), they are increasingly threatened by roads, fencing, subdivisions, and other development. Over the last decade, many new tracking studies have been conducted on migratory herds, and analytical methods have been developed that allow for population-level corridors and stopovers to be mapped and prioritized. In 2018, the U.S. Geological Survey assembled a Corridor Mapping Team to provide technical assistance to western states working to map bison, elk, moose, mule deer, and pronghorn migrations using existing Global Positioning System data. Led by the Wyoming Cooperative Fish and Wildlife Research Unit, the team consists of federal scientists, university researchers, and biologists and analysts from participating state agencies.

In its first year, the team has worked to develop standardized analytical and computational methods and a workflow applicable to datasets typically collected by state agencies. In 2019, the team completed analyses necessary to map corridors, stopovers, routes and winter ranges in Arizona, Idaho, Nevada, Utah, and Wyoming. A total of 26 corridors, 16 migration routes, 25 stopovers, and 9 winter ranges were mapped across these states and are included in this report. This report and associated data release provide the means for the habitats required for migration to be taken into account by state and federal transportation officials, land and wildlife managers, planners, and other conservationists working to maintain big-game migration in the western states.

Introduction

Across the American West, many ungulate herds migrate to exploit key resources that shift seasonally across topographically diverse landscapes (Kauffman and others, 2018). Migration promotes abundant populations by enhancing foraging opportunities and reducing risk of exposure to adverse conditions (Bolger and others, 2008). Evidence of the importance of migration can be found throughout western landscapes as well as more broadly across the globe. For example, migratory herds of *Connochaetes taurinus* (blue wildebeest) in east Africa often outnumber resident counterparts by an order of magnitude (Fryxell and others, 1988). Many western U.S. landscapes contain a juxtaposition of mountains and plains or sagebrush basins, wherein the best forage is produced in mountain habitats fed by winter snowmelt and summer precipitation. Thus, many herds migrate into the mountains in spring in search of high-quality forage (Albon and Langvatn, 1992). The mountains become largely inhospitable, however, once winter advances and blankets the high country with snow. All species of

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ungulates suffer elevated energy costs when forced to move through deep snow (reviewed in Parker and others, 2009). The migratory cycle is complete when animals move out of the high country in early winter and head for low-elevation basins, where snow levels are relatively shallow and some forage remains accessible. Migration is recognized as a ubiquitous behavior that allows ungulates to survive and thrive in seasonal landscapes that characterize the American West.

Mapping Migration

Wildlife managers have recognized the importance of migration since the early 19th century. Early trappers and explorers commonly made observations about the seasonal movements of the ungulate herds. Comments such as, “In the spring, as the snows disappears and the young grass starts, they return by the same route…” can easily be found in early records (Kauffman and others, 2018). American Indians had seasonal hunting circuits that were timed to access the flow of animals coming in and out of the mountains. Although the knowledge of these movements existed, maps of historical migrations are mostly non-existent.

The first detailed maps of ungulate migrations were of *Cervus canadensis* (elk) migrating in and out of Yellowstone National Park in the 1960s, conducted by Frank and John Craighead (Craighead and others, 1972a; Craighead and others, 1972b). The Craigheads caught elk in clover traps and fit them with color-banded neckbands, allowing them to be resighted up in the mountains on summer range (Craighead and others, 1972a). Such studies only gave a broad understanding of general movements between winter and summer ranges. Starting in the 1970s, Very High Frequency (VHF) radio collars allowed animals to be relocated infrequently by ground or air via triangulation (Kays and others, 2015). VHF studies often provided an animal’s location every 1–2 weeks depending on the field effort involved; such methods provided the first coarse-scale maps of migratory movements. In the 2000s, Global Positioning System (GPS) technology became widely available to wildlife researchers. Currently, tracking technology continues to evolve with longer-lasting batteries, better data storage, and satellite transmission options. With the ability to record animal locations every 1–2 hours for several years, modern-day GPS collars provide a detailed path of the year-round movements of ungulates and other large-bodied animals (Kays and others, 2015).

The use of GPS collars on ungulate taxa has brought about a renaissance in animal tracking and, along with it, has allowed discovery and delineation of migrations across the West (Sawyer and others, 2009b). In many cases, wildlife managers knew that specific herds were migratory, but lacked detailed delineation of the migrations. Some herds have been found to migrate farther than biologists and land managers had anticipated. This was the case for Wyoming’s Sublette *Odocoileus hemionus* (mule deer) herd in south-central Wyoming. The remarkable 150-mile migratory journey was recently discovered, revealing that many of the animals migrate from their Red Desert winter range near Superior, Wyo., to lush and productive summer ranges in the headwaters of the Hoback River (Sawyer and others, 2016). This is just one example of new data on the migration routes of mule deer, elk, and *Antilocapra americana* (pronghorn) that have been collected by state wildlife agencies in the West. Wildlife biologists and managers are collecting detailed location data from unmapped herds each year.

Migration Ecology

In addition to allowing delineation of migration routes, fine-scale GPS data have enabled new scientific discoveries. For example, although wildlife biologists have known for some time that migratory ungulates move into the mountains in spring to access higher-quality forage, they predicted that migratory herbivores—including waterfowl (Drent and others, 1978)—would time their movements in spring to seek out new forage that is reasonably abundant yet still young enough to be highly digestible. Tracking waves of spring green-up is referred to as “surfing the green wave” (van der Graaf and others, 2006). Sawyer and Kauffman (2011) showed that mule deer spend nearly 95 percent of their time during spring migration held up in stopovers used primarily for foraging. To empirically test the idea that ungulates surf the green wave, Bischof and others (2012) examined movements of *Cervus elaphus* (Norwegian red deer) by first developing the means of measuring spring green-up using remotely sensed measures of plant growth (the Normalized Difference Vegetation Index [NDVI]). When this method was applied to migratory mule deer in Wyoming, researchers found strong evidence of surfing: in a two-month long migration, nearly one-third of collared mule deer moved in nearly complete coordination with green-up as it moved up in elevation in spring (Aikens and others, 2017).

Other ungulate taxa have been found to coordinate their movements with seasonal green-up as well (Merkle and others, 2016). Although less work has been conducted on the timing of the fall migration, it is clear that the onset of snow and cold temperatures—or hunting pressure or supplemental feeding in some limited cases (Cleveland and others, 2012)—cause animals to initiate their fall movements out of the high country (Monteith and others, 2011; Jones and Carter, 2016). These studies, combined with recent work documenting the nutritional benefit of surfing in elk populations (Middleton and others, 2018), indicate that animals require the ability to freely move along their corridors in order to derive the foraging benefits of migration.

Ungulates can migrate hundreds of kilometers along the same migratory routes year after year, and studies are beginning to identify how they know how to make these journeys (Sawyer and others, 2019). In general, migratory taxa navigate along their routes using either learned or genetic information. For example, common-garden experiments in migratory birds have shown that both migration timing and compass direction of migration are heritable traits (reviewed in Merlin and Liedvogel, 2019). But in mammals, it has been thought that migrations must be learned, and presumably passed on from mother to young (Nelson, 1998). A breakthrough came in 2018, when Jesmer and others (2018) showed that reintroduced *Ovis canadensis* (bighorn sheep) and reestablished *Alces alces* (moose) populations failed to migrate in their new habitats, indicating the lack of a genetic program to do so. Reintroduced animals did not surf well either, but they learned. Their ability to surf increased over multiple generations, as did their propensity to migrate. Notably, these animals required 30–80 years of learning a new landscape to develop migratory behavior, suggesting that a complete loss of migratory behavior can have dire consequences for populations (Jesmer and others, 2018).

Numerous studies have shown that animals must learn complex behaviors, such as the migrations of whooping cranes (Mueller and others, 2013) or the homing of pigeons (Sasaki and Biro, 2017). In *Loxodonta Africana* (African elephants), the older matriarchs possess knowledge about resource distribution (for example, water sources) that younger animals have not yet learned (McComb and others, 2001). Increasingly, researchers understand that the detailed knowledge required to make seasonal migrations is best thought of as a form of animal culture, built up through time, and transmitted between generations (Whiten, 2019). Such past experiences may often lead to a diverse portfolio of migratory strategies (Lowrey and others, 2019), which is likely to promote stability and persistence at the population level. This is a cautionary tale for the conservation of migration corridors, because it means that not only must the corridors be kept intact, but the specific animals that retain the knowledge of these journeys must be conserved as well (Brakes and others, 2019). The decades that it will take for the culture of migration to return once lost, suggests that restoring lost migrations is likely to be a nearly impossible task.

While mapping of migration has proliferated, so too has our understanding of the threats that many migrating animals now face. Migration requires free movement across large landscapes, but western landscapes are increasingly fragmented by many types of barriers. Fences are a persistent feature of many habitats; they are often navigable by migrating big game but remain a source of direct mortality (Harrington and Conover, 2006). For some species (like pronghorn) and some fence types (tall, woven wire), the stretch of fences across public and private rangelands can significantly impair movements, including long-distance migration (Gates and others, 2012; Jones and others, 2019). Housing development in the West has a constant and growing effect on migration corridors because subdivisions and other housing are permanent (Kauffman and others, 2018; Monteith and others, 2018). For example, migrating mule deer avoided stopping over near housing developments during migration (Wyckoff and others, 2018).

Roads are an additional source of mortality, which also constrain connectivity in the western United States (Huijser and others, 2017) and worldwide (Brown and Ross, 1994). Each year, thousands of animals are killed on the nation's roadways (Conover and others, 1995), many during their spring or fall migrations (Sawyer and others, 2012). Perhaps more importantly, roads—especially those with high traffic—are an increasingly formidable barrier to movement and can truncate migrations or cause loss of migration (Kauffman and others, 2018). Finally, the rapid pace of energy development represents a new challenge for migrating big game. Mule deer have been found to avoid energy development in various ways (Lendrum and others, 2012; Sawyer and others, 2013; Wyckoff and others, 2018) including speeding up, stopping over less, or detouring around gas-development areas during migration. Such behavioral modifications can result in a mismatch between migration and peak green-up, which diminishes the foraging benefit of migration (Sawyer and others, 2013).

Applying Migration Science to Conservation and Wildlife Management

The identification and mapping of migration corridors has proven to be a powerful means to advance science-based conservation and wildlife management (Kauffman and others, 2018). Studying and mapping corridors and routes helps managers and researchers alike better understand the unique habitat needs of big game herds (Berger and others, 2008; Monteith and others, 2018), which has long been a goal of applied wildlife research. Moreover, state wildlife managers, federal land managers, and other conservation groups have demonstrated for more than a decade that corridor identification can facilitate critical on-the-ground management and conservation (for example, Sawyer and others, 2014). Modern approaches of corridor mapping through methods such as Brownian bridge movement modeling provide a polygon with defined width and intensity of use by marked animals, which can be simply overlayed with threats and conservation actions (Sawyer and others 2009b). In Wyoming alone, conservation groups, wildlife, and land managers have worked to convert hundreds of miles of fence within identified corridors to be wildlife friendly. In the Greater Yellowstone Ecosystem, encompassing Montana, Idaho and Wyoming, land trusts are currently working to secure conservation easements on large portions of private ranches within identified corridors, with investments in the tens of millions of dollars. There are a growing number of successful highway crossing structures built across western states, which were informed by migration corridors (for example, Sawyer and others, 2012) or otherwise guided by the seasonal movement needs of big game, such as two recently built overpasses on Interstate-80 (I-80) and five crossing structures on U.S. Highway 93 in Nevada (Simpson and others, 2016). In summary, the identification and mapping of big game migration corridors is an effective tool for science-based wildlife management that will allow western states to sustain the migration corridors of their big-game herds by identifying barriers to movements and other conservation opportunities.

In 2019, the U.S. Geological Survey (USGS) assembled a Corridor Mapping Team consisting of USGS researchers and state wildlife managers from western states. This team was formed to facilitate the mapping of mule deer, elk, and pronghorn migrations, using existing data collected by participating states. The Corridor Mapping Team worked to identify and prioritize state datasets for analyses to map corridors, routes, stopovers and winter ranges of bison, moose, mule deer, elk, and pronghorn using GPS data with a relocation frequency that varied from a GPS location acquired every 2–24 hours. This collaborative approach allowed individual states to set their own priorities for corridor mapping, while making use of technical support and expertise from the broader mapping team. This report is a first effort to document the big-game migration corridors of participating states, using standardized methods (Sawyer and others, 2009b). Our hope is that this work can provide a common methodology and platform to enable corridor delineations to be incorporated into conservation planning and wildlife management efforts (Kauffman and others, 2020).

Mule Deer

Mule deer have a large geographic range that covers the western half of North America, extending from the Yukon to Mexico (fig. 1). The scientific name “hemionus” means half-mule and refers to the large ears of mule deer that help distinguish them from their cousin, the *Odocoileus virginianus* (white-tailed deer). Within their expansive geographic range, mule deer have adapted to a variety of different ecoregions, including coastal rainforests, the Great Plains, the deserts of the Southwest, and the Rocky Mountain basin and range (Kie and Czech, 2000).

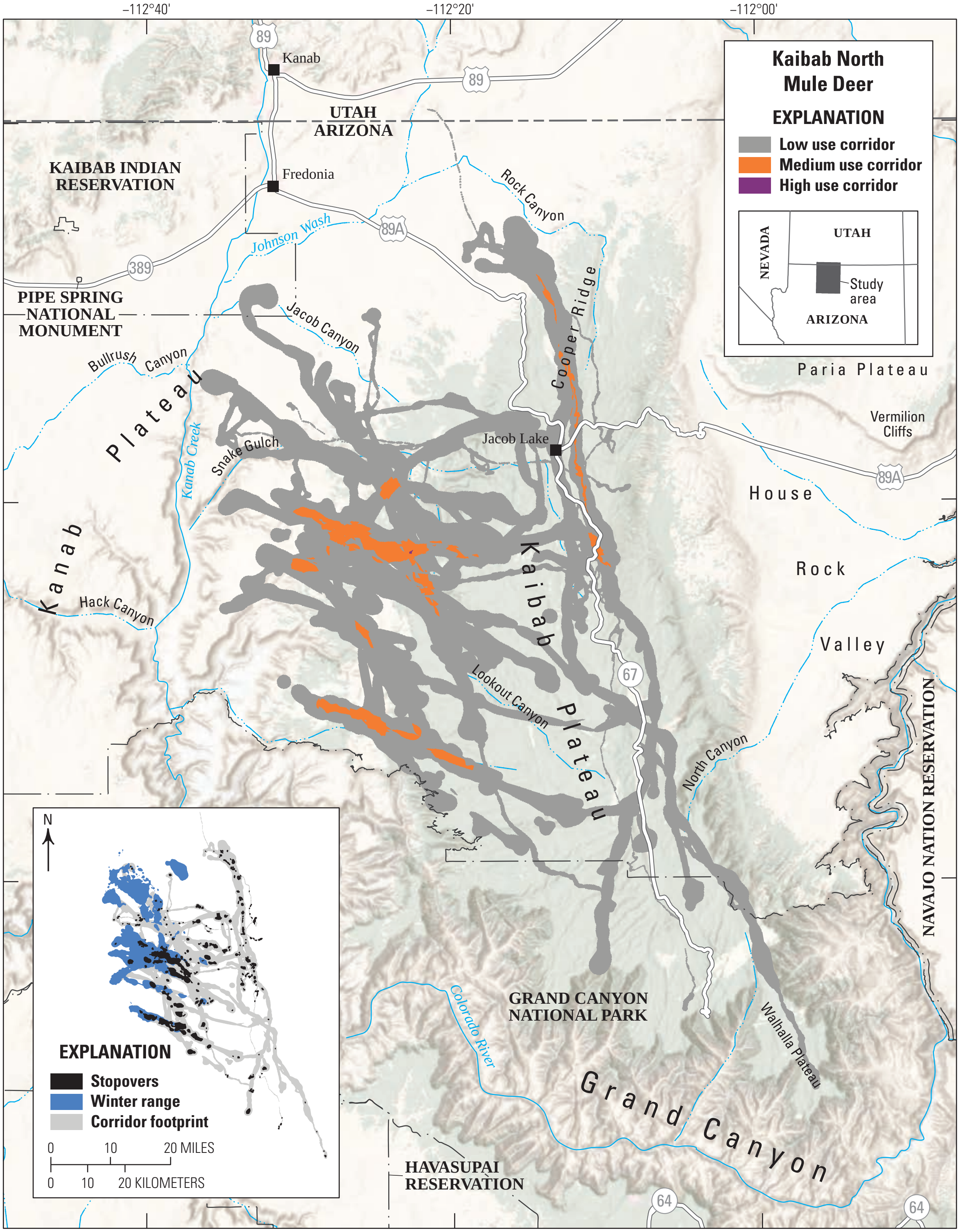
Larger ungulates like moose and elk can ingest significant amounts of coarse forage that may not have high nutrional value. In contrast, mule deer are selective feeders that forage on plants that provide concentrated and highly digestible nutrients (Short, 1981). Mule deer are generally considered browsers rather than grazers, but they do prefer herbaceous forage when it is seasonally available in the spring and summer. When herbaceous forage is not available, mule deer often rely on native shrub species like *Artemisia tridentata* (sagebrush), *Purshia tridentata* (antelope bitterbrush), *Cercocarpus ledifolius* (curl-leaf mountain mahogany), *Purshia stansburyana* (cliffrose), and *Amelanchier utahensis* (western serviceberry).

Mule deer show strong fidelity to their seasonal ranges and migration routes (Sawyer and others, 2019). Although some populations are resident, the largest and most productive mule deer herds tend to be migratory and may travel anywhere from 10 to 150 miles (mi) (16–241 kilometers [km]) between seasonal ranges. Like other ungulates, mule deer usually migrate along elevational or moisture gradients that enable access to seasonal peaks in high-quality forage (Sawyer and Kauffman, 2011). Spring migrations tend to be synchronized with vegetation green-up, whereas autumn migrations often correspond with snow events or vegetation senescence (Monteith and others, 2011). The breeding season or “rut” usually occurs from November to December, and females give birth to one or two fawns in the following June to July, depending on habitat productivity and their body condition.

Mule deer and other big game were scarce by the early 1900s because of unrestricted hunting. However, by the 1930s, hunting restrictions and wildlife management practices allowed mule deer populations to recover and by the 1950s and 60s, mule deer populations flourished. In the early 1970s, mule deer populations across the western United States began to gradually decline (Kauffman and others, 2018). Today, the trajectory of mule deer populations varies regionally, with some stable or increasing, while others continue to decline. As of 2019, the Western Association of Fish and Wildlife Agencies estimated mule deer numbers totaled approximately three million across their range (Mule Deer Working Group, 2019). The key threats and challenges to mule deer conservation also vary by region, but generally include habitat loss, disease (for example, chronic wasting disease), habitat fragmentation and loss of connectivity (for example, roadways, fences, dense development), and changing environmental conditions (for example, vegetation succession, drought, climate change).

In this report, select mule deer migrations have been mapped for Arizona, Idaho, Nevada, Utah, and Wyoming. The mapping of corridors, routes, stopovers, and winter ranges follows a standard procedure, largely based on the approach of Sawyer and others (2009b). Methodological details are given in the summary statistics associated with each map. The analytical methods common to all analyses, including those specific to species or states, are provided in Appendix 1. For Wyoming herds, the report shows corridors that have been officially designated by the Wyoming Game and Fish Department; if a corridor has not yet been designated, only the routes (in other words, lines) are shown in the associated maps.

Figure 1. Current range of mule deer in North America (Demarais and Krausman, 2000).



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

Figure 2. Migration corridors, stopovers, and winter ranges of the Kaibab North mule deer herd.

Arizona | Mule Deer

Kaibab North Mule Deer Migration Corridors

Mule deer of the Kaibab North herd on the Kaibab Plateau are treasured for their historic and contemporary significance in North America. They are the densest population of mule deer in Arizona, with an estimate of 10,200 individuals in 2019. This report compiles two research efforts, the first completed by Arizona Game and Fish Department in 2014, and the second from Utah Division of Wildlife's ongoing research started in 2017 (fig. 2). The Kaibab Plateau is bound on the east, south, and west by vertical canyon walls which run along the Colorado River and Kanab Creek. The Kaibab North Deer herd winters among pinyon-juniper, sagebrush, and cliffrose landscapes along the west, east, and northern extents of the plateau. Portions of the Kaibab North herd in Arizona and the Paunsaugunt Plateau herd in Utah share a common winter range along the Arizona and Utah border. Their summer range consists of habitat dominated by ponderosa pine, mixed conifer, and aspen. There are currently few impediments to mule deer migration on the Kaibab Plateau. Water availability throughout seasonal ranges may be the limiting factor for this population.

Animal Capture and Data Collection

Sample size: 34 female/12 male mule deer (26 Ariz.; 20 Utah)

Relocation frequency: ~6 hours (Ariz. study); ~2 hours (Utah study)

Project duration: 2012–2014 (Ariz. study); 2017–present (Utah study)

Data Analysis

Corridor, stopover, and winter range analysis: Brownian bridge movement models (Sawyer and others 2009b); corridor analysis used Fixed Motion Variance movement models (see further description in appendix)

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

Models derived from:

- Migration: 96 sequences from 41 individuals (55 spring sequences, 41 fall sequences)
- Winter: 44 sequences from 30 individuals

Corridor and Stopover Summary

Migration start and end date (median):

- Spring: April 21 to May 3
- Fall: October 21 to November 13

Average number of days migrating:

- Spring: 15 days
- Fall: 23 days

Migration corridor length:

- Min: 11 mi (17.7 km)
- Mean: 28 mi (45.1 km)
- Max: 93 mi (149.7 km)

Migration corridor area:

- 245,264 acres (99,254.8 ha) (low use)
- 12,915 acres (5226.5 ha) (medium use)
- 17 acres (6.9 ha) (high use)

Stopover area: 25,105 acres (10,159.6 ha)

Winter Range Summary

Winter start and end date (median):

- December 15 to April 9

Winter length (mean): 105 days

Winter range (50 percent contour) area: 83,915 acres (33,959.2 ha)

Other Information

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- Jeff Gagnon (jgagnon@azgfd.gov), Wildlife Specialist Regional Supervisor, 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:

- Carrel, W.K., Ockenfels, R.A., and Schweinsburg, R.E., 1999, cae—Research Branch Technical Report No. 29: Phoenix, Ariz., Arizona Game and Fish Department, p. 44.

Photograph from Lucas Olson.

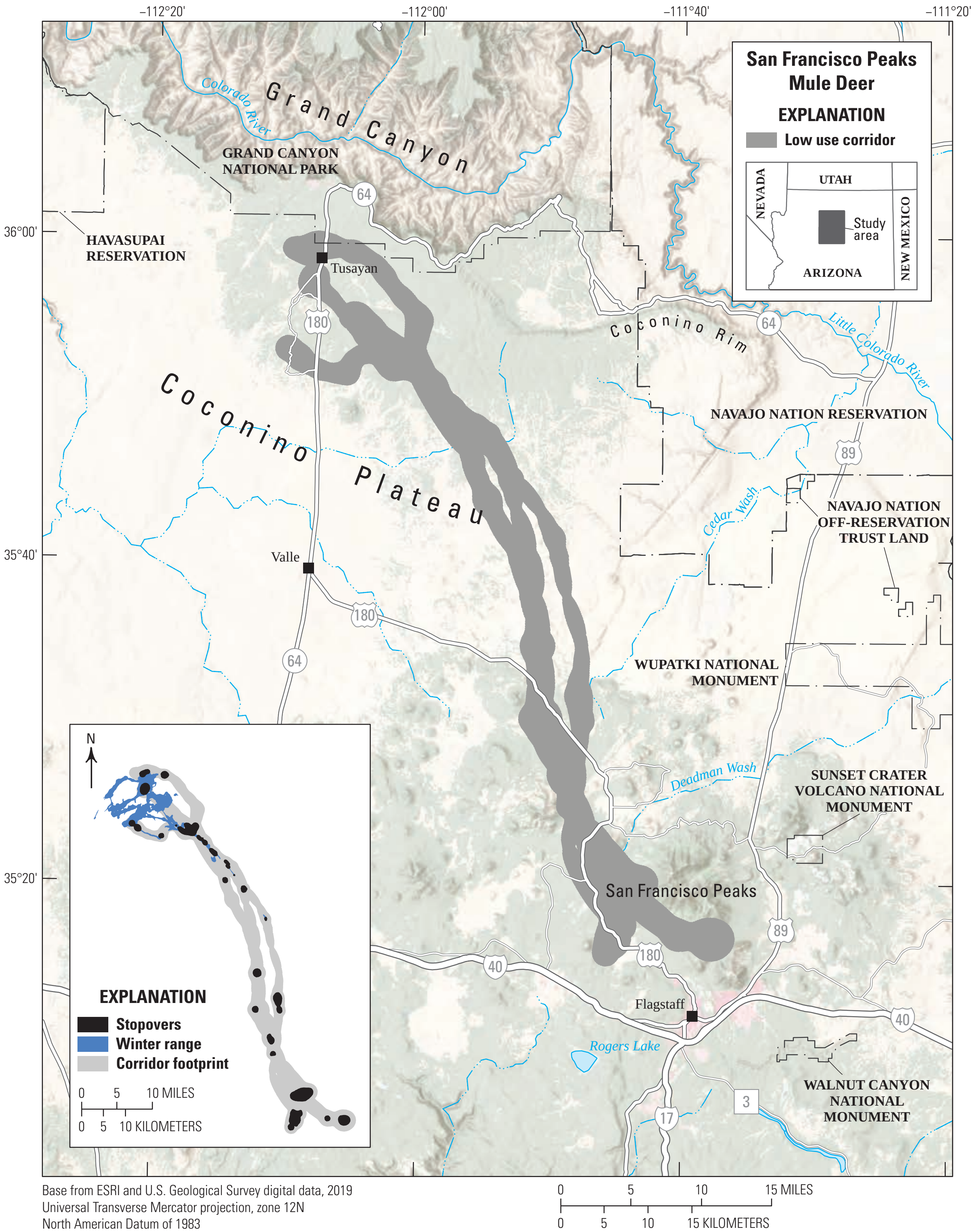


Figure 3. Migration corridors, stopovers, and winter ranges of the San Francisco Peaks mule deer herd.

Arizona | Mule Deer

San Francisco Peaks Mule Deer Migration Corridors

The San Francisco Peaks mule deer herd makes one of Arizona's most extraordinary annual migrations between Flagstaff, Ariz. and the Grand Canyon (fig. 3). In 2008, 13 mule deer were GPS collared near the South Rim of the Grand Canyon to collect data that would help researchers understand the impact of Arizona's State Route 64 on mule deer movement. Unexpectedly, 4 individuals migrated over 50 mi (80 km) to summer range near the San Francisco Peaks, north of Flagstaff, containing alpine, subalpine, and ponderosa pine habitats. The GPS collars dropped in 2009, but questions surrounding this long-distance migration remained. In June 2019, the Arizona Game and Fish Department GPS collared 20 mule deer from the San Francisco Peaks herd to learn more about this population on their summer range in Game Management Unit (GMU) 7E/7W, where an estimated 5,300 mule deer reside. To learn more about this population, the primary challenges to mule deer in this migration corridor are related to navigating highways. These deer must traverse two major highways, U.S. Highway 180 and State Route 64, which experience high traffic volumes from tourists visiting the Grand Canyon.

Animal Capture and Data Collection

Sample size: 8 female/1 male adult mule deer
Relocation frequency: ~2 hours
Project duration: March 2008–November 2009

Data Analysis

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

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

Models derived from:

- Migration: 6 sequences from 4 individuals (4 spring sequences, 2 fall sequences)
- Winter: 8 sequences from 7 individuals

Corridor and Stopover Summary

Migration start and end date (median):

- Spring: April 23 to April 28
- Fall: October 10 to October 15

Average number of days migrating:

- Spring: 8 days
- Fall: 6 days

Migration corridor length:

- Min: 52 mi (83.7 km)
- Mean: 54 mi (86.9 km)
- Max: 56 mi (90.1 km)

Migration corridor area:

- 146,213 acres (59,170.3 ha) (low use)

Stopover area: 14,950 (6050.1 ha) acres

Winter Range Summary

Winter start and end date (median):

- October 25 to March 23

Winter length (mean): 86 days

Winter range (50 percent contour) area: 25,649 acres (10,379.8 ha)

Other Information

Project contacts:

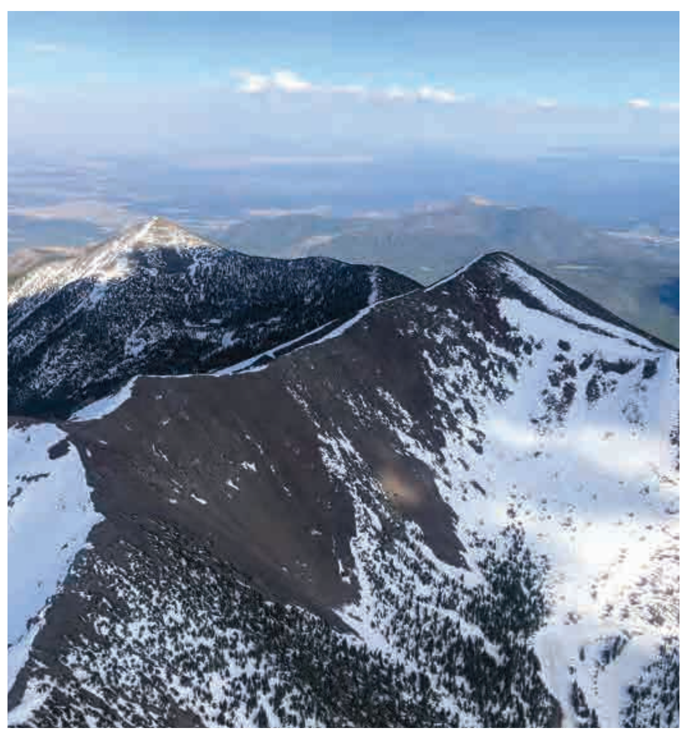
- Jeff Gagnon (jgagnon@azgfd.gov), Wildlife Specialist Regional Supervisor, Arizona Game and Fish Department

Data analyst:

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

Reports and publications:

- Dodd, N. L., J. W. Gagnon, S. C. Sprague, S. Boe, and R. E. Schweinsburg. 2012. Wildlife accident reduction study and monitoring: Arizona State Route 64. Final project report 626, Arizona Department of Transportation Research Center, Phoenix, Ariz.



Photograph from Haley Nelson.

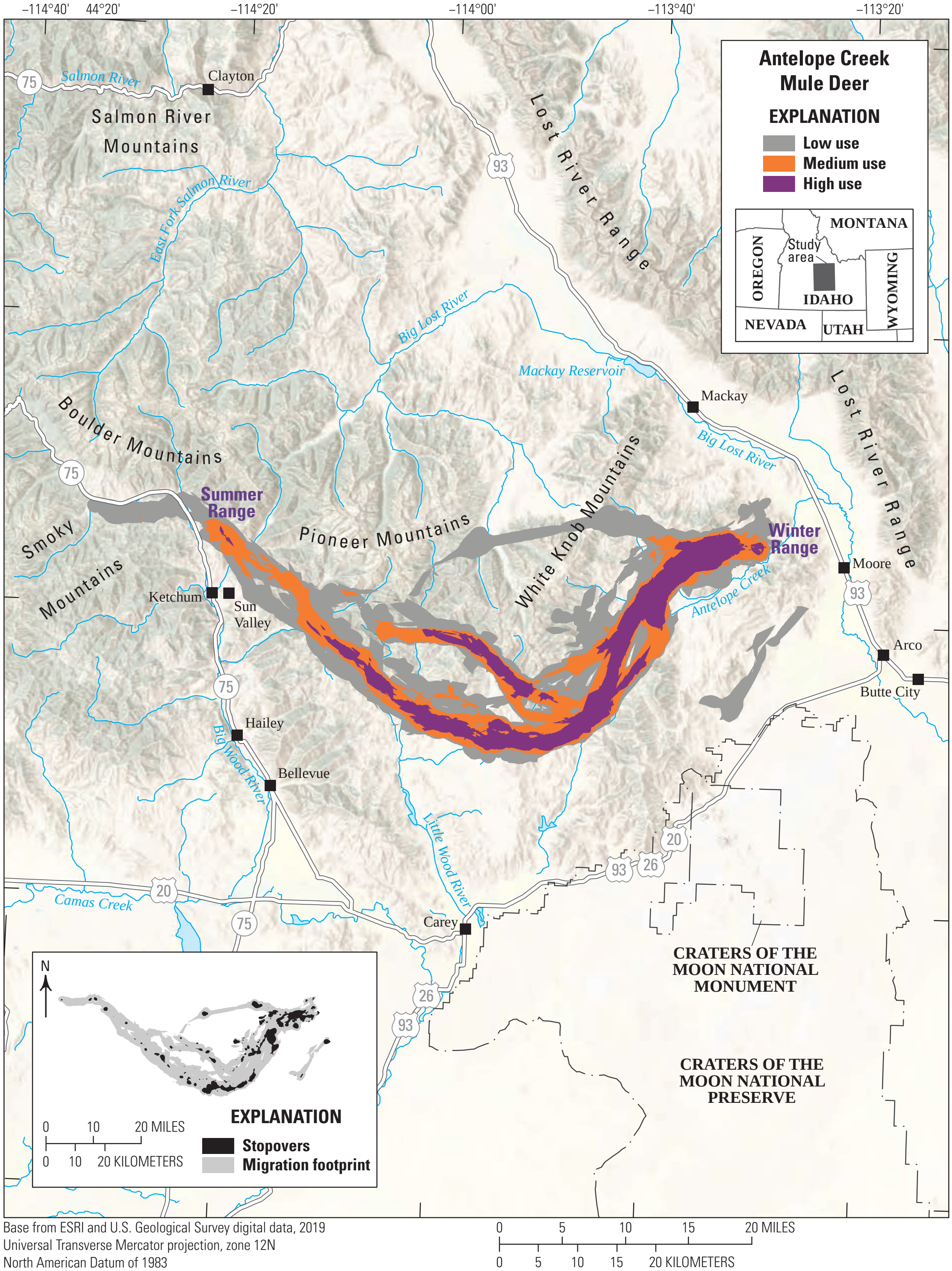


Figure 4. Migration routes and stopovers of the Antelope Creek mule deer herd.

Idaho | Mule Deer

Antelope Creek Mule Deer Migration Routes

Antelope Creek mule deer winter along Antelope Creek, west of Big Lost River (fig. 4). The area provides crucial forage and habitat for mule deer, especially when winters are severe. The rolling hills and steep, rocky slopes of Antelope Creek hold between 1,300 and 1,850 mule deer during winter (based on aerial surveys in 2006 and 2010). These mule deer migrate westward through the White Knob and Pioneer Mountains towards Ketchum and the northern portions of GMU 49 and 50. On average, Antelope Creek mule deer travel more than 42 mi (68 km) to migrate between summer and winter ranges with the farthest individuals traveling close to 110 mi (177 km). The Antelope Creek mule deer are adjacent to the Appendicitis Hills deer herd (950–2,120 deer). Individuals may move between these two areas during winter and often share migration routes and summer ranges. Currently, there are no known significant migration challenges for this deer herd, but continued development of infrastructure and loss of native habitat across their range could result in cumulative impacts over time.

Animal Capture and Data Collection

Sample size: 99 adult female mule deer
Mean relocation frequency: ~16 hours
Project duration: April 20, 2011–December 22, 2018

Data Analysis

Migration and stopover analysis: Brownian bridge (Sawyer and others 2009b) and Fixed Motion Variance movement models (see further description of methods in appendix)

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

Models derived from:

- Migration: 99 sequences from 41 individuals (59 spring sequences, 40 fall sequences)

Migration and Stopover Summary

Migration start and end date (median):

- Spring: April 8 to May 16
- Fall: October 14 to November 20

Days migrating (mean):

- Spring: 38 days
- Fall: 37 days

Migration length:

- Min: 5.6 mi (9.0 km)
- Mean: 42.4 mi (68.2 km)
- Max: 109.8 mi (176.7 km)

Migration area:

- 223,868 acres (90,596.1 ha) (low use; 10 percent)
- 102,606 acres (41,523.2 ha) (medium use; 10–20 percent)
- 49,853 acres (20,174.8 ha) (high use; > 20 percent)

Stopover area: 35,984 acres (14,562.2 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
- Mike McDonald (mike.mcdonald@idfg.idaho.gov), Regional Wildlife Manager, Idaho Department of Fish and Game

Data analyst:

- Jodi Berg, Sr. Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming
- Scott Bergen, Sr. 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, *in* Meints, D.R.: Boise, Idaho, Idaho Department of Fish and Game.
- Hurley, M., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Idaho Department of Fish and Game, Boise, Idaho.

Photograph from John Stolzman.

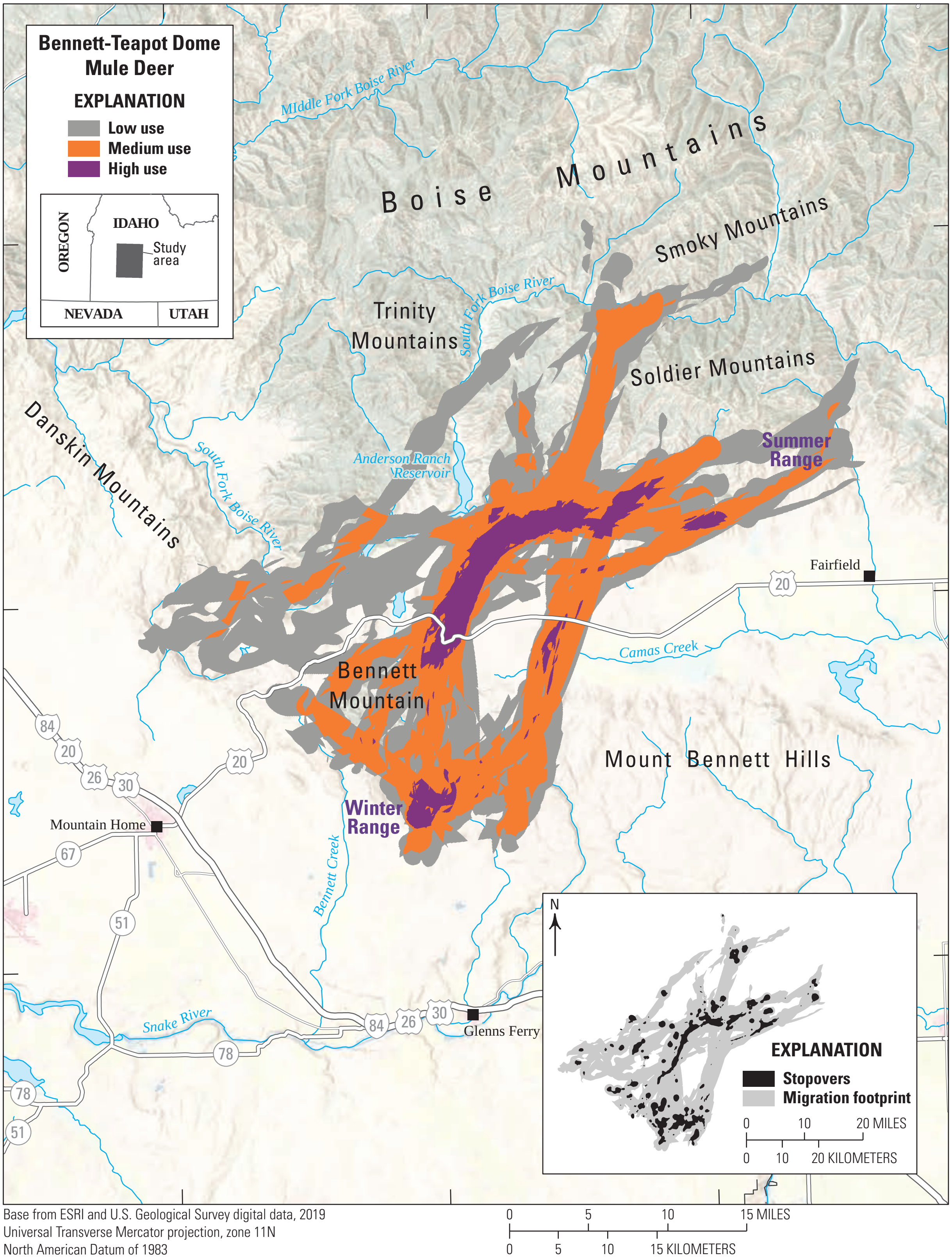


Figure 5. Migration routes and stopovers of the Bennett-Teapot Dome mule deer herd.

Idaho | Mule Deer

Bennett-Teapot Dome Mule Deer Migration Routes

Bennett mule deer inhabit the foothills between Mountain Home and Bennett Mountain (fig. 5). Mule deer wintering in this area typically traverse the Bennett Mountains using several migration pathways (two major, one moderate, and several low-use) to reach summer ranges east of the Trinity Mountains in the Soldier and Smoky Mountains. Bennett-Teapot Dome mule deer migrate on average 38 mi (61 km) between summer and winter range, with the longest routes reaching more than 60 mi (97 km). Deer used for this analysis winter in two Population Management Units (PMUs): Smoky-Bennett (GMUs 43, 44, 45, 48, and 52) and Boise (GMU 39). The 2018 population estimate for mule deer in the Smoky-Bennett was 16,358.

Animal Capture and Data Collection

Sample size: 40 adult female mule deer
Mean relocation frequency: ~15 hours
Project duration: March 28, 2013–December 2, 2018

Data Analysis

Migration and stopover analysis: Brownian bridge (Sawyer and others, 2009b) and Fixed Motion Variance movement models (see further description of methods in appendix)

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

Models derived from:

- Migration: 105 sequences from 40 individuals (57 spring sequences, 48 fall sequences)

Migration and Stopover Summary

Migration start and end date (median):

- Spring: April 16 to May 12
- Fall: October 4 to October 30

Days migrating (mean):

- Spring: 26 days
- Fall: 26 days

Migration length:

- Min: 20.6 mi (33.2 km)
- Mean: 38.5 mi (62.0 km)
- Max: 62.4 mi (100.4 km)

Migration area:

- 337,165 acres (136,445.8 ha) (low use; 10 percent)
- 155,370 acres (62876.0 ha) (medium use)
- 27,720 acres (11,217.9 ha) (high use)

Stopover area: 52,960 acres (21,432.2 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:

- Jodi Berg, Sr. Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming
- Scott Bergen, Sr. 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, *in* Meints, D.R.: Boise, Idaho, Idaho Department of Fish and Game.
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game.

Photograph from Rick Ward.

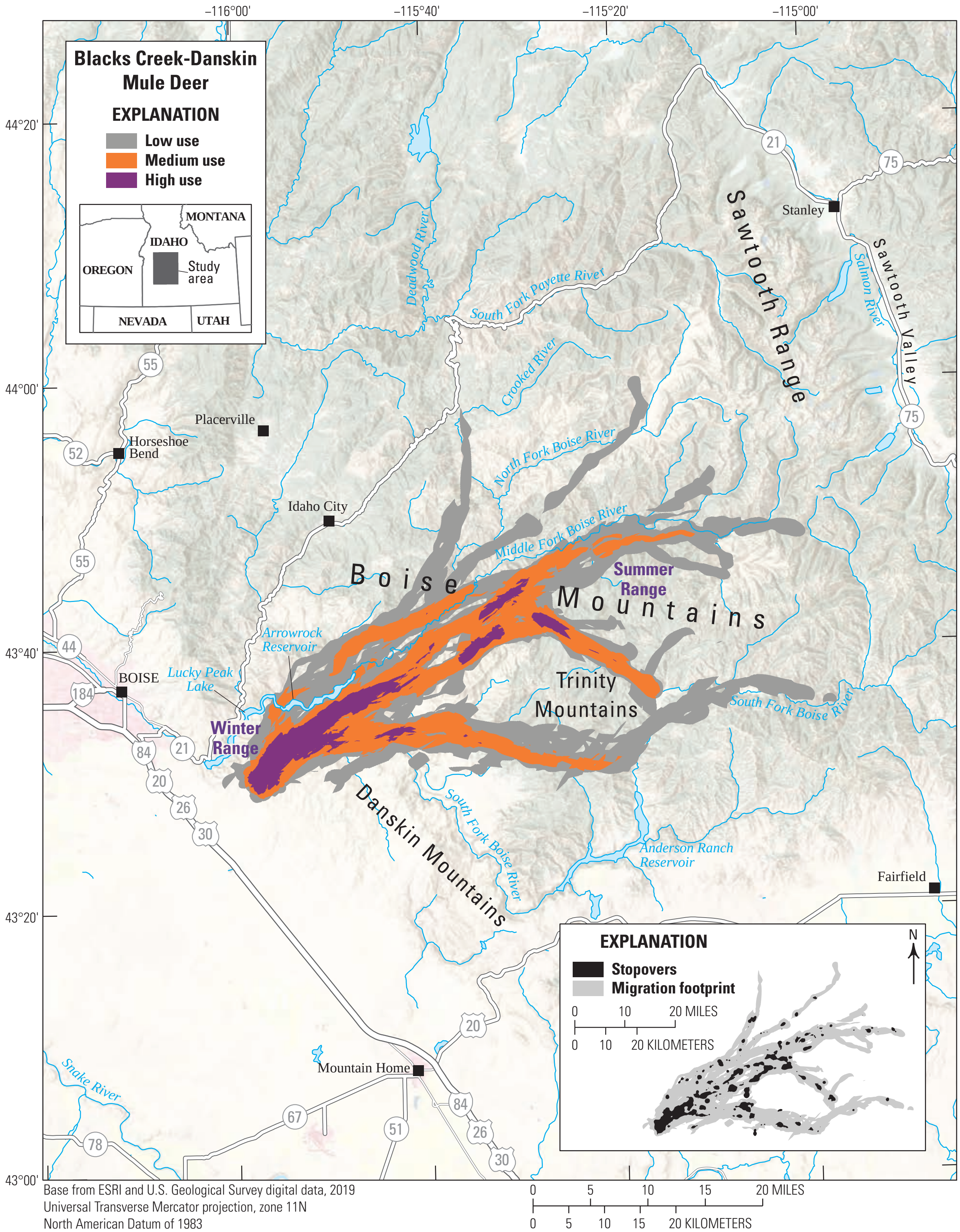


Figure 6. Migration routes and stopovers of the Blacks Creek-Danskin mule deer herd.

Idaho | Mule Deer

Blacks Creek-Danskin Mule Deer Migration Routes

Blacks Creek-Danskin mule deer winter in the foothills southeast of Lucky Peak Lake (fig. 6). During their spring migration, these mule deer move into reaches much farther up in the valley of the Middle Fork Boise River. They may also travel as far as the Sawtooth Valley. On average, Blacks Creek-Danskin mule deer migrate more than 40 mi (64 km) between winter and summer range, with some individuals migrating up to 75 mi (121 km). The 2018 population estimate for mule deer in the Boise PMU was 28,600.

Animal Capture and Data Collection

Sample size: 48 adult female mule deer
Mean relocation frequency: ~16 hours
Project duration: March 15, 2015–December 17, 2018

Data Analysis

Migration and stopover analysis: Fixed Motion Variance movement models (see further description of methods in appendix)

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

Models derived from:

- Migration: 119 sequences from 48 individuals (73 spring sequences, 46 fall sequences)

Migration and Stopover Summary

Migration start and end date (median):

- Spring: April 8 to May 4
- Fall: October 9 to November 20

Days migrating (mean):

- Spring: 25 days
- Fall: 42 days

Migration length:

- Min: 8.7 mi (14.0 km)
- Mean: 40.4 mi (65.0 km)
- Max: 76.3 mi (122.8 km)

Migration area:

- 327,036 acres (132346.8 ha) (low use; 10 percent)
- 129,053 acres (52,225.9 ha) (medium use; 10–20 percent)
- 29,801 acres (12060.0 ha) (high use; >20 percent)

Stopover area: 50,933 acres (20,611.9 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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Data analyst:

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- Scott Bergen, Sr. 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, *in* Meints, D.R.: Boise, Idaho, Idaho Department of Fish and Game.
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game.

Photograph from Rick Ward.

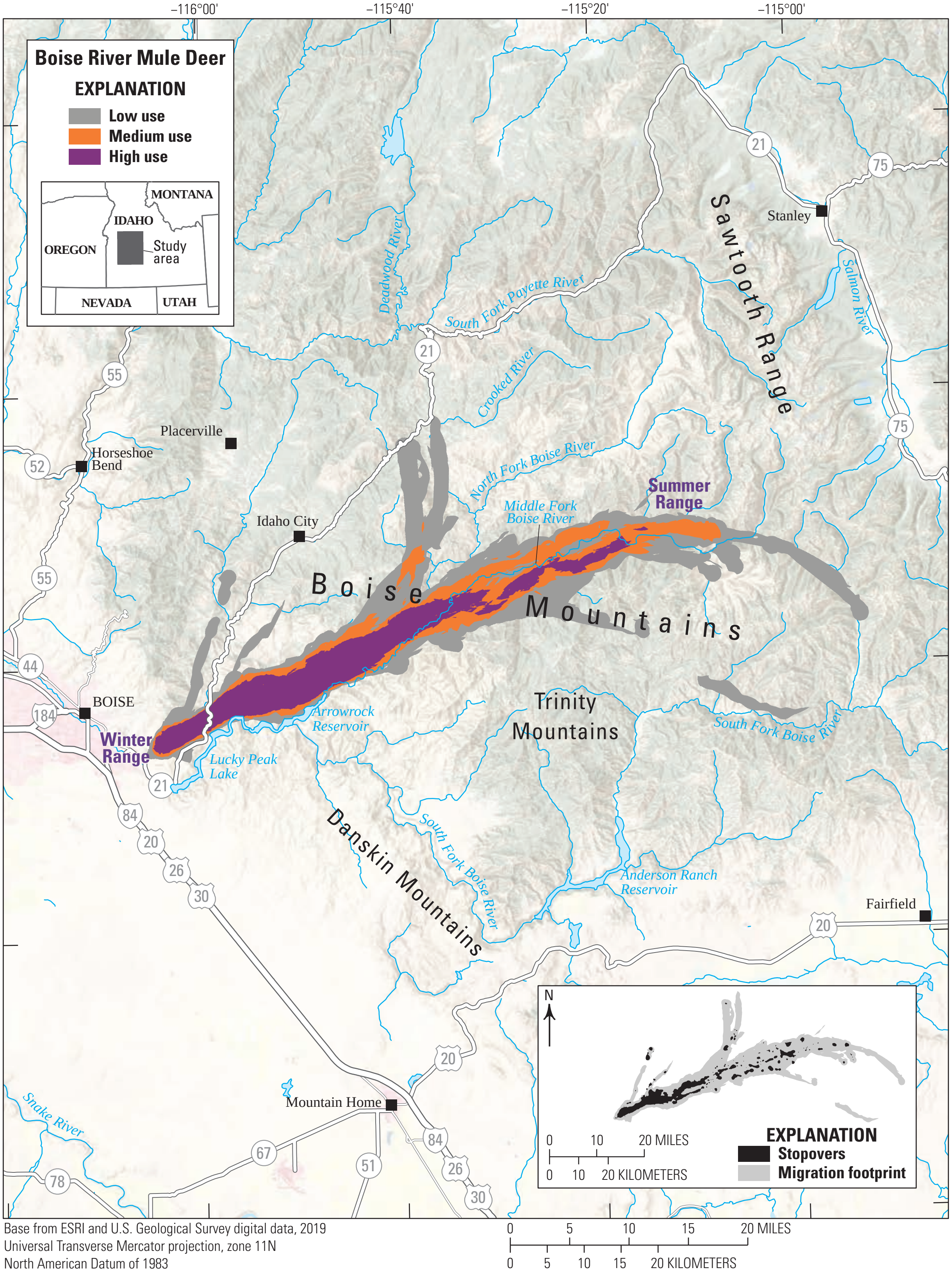

Figure 7. Migration routes and stopovers of the Boise River mule deer herd.

Idaho | Mule Deer

Boise River Mule Deer Migration Routes

In winter, Boise River mule deer inhabit the foothills west of Lucky Peak Lake (fig. 7). Mule deer wintering in this area typically traverse the valley of the Middle Fork Boise River into reaches much farther up the valley and may travel as far as the Sawtooth Mountains. On average, Boise River mule deer migrate more than 45 mi (72 km) between summer and winter range, while the longest migrations are close to 96 mi (154 km). The 2018 population estimate for mule deer in the Boise PMU was 28,600.

Animal Capture and Data Collection

Sample size: 52 adult female mule deer
Mean relocation frequency: ~17 hours
Project duration: April 20, 2011–December 10, 2018

Data Analysis

Migration and stopover analysis: Brownian bridge (Sawyer and others 2009b) and Fixed Motion Variance movement models (see further description of methods in appendix)

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

Models derived from:

- Migration: 119 sequences from 52 individuals (76 spring sequences, 43 fall sequences)

Migration and Stopover Summary

Migration start and end date (median):

- Spring: April 1 to May 7
- Fall: October 11 to November 11

Days migrating (mean):

- Spring: 36 days
- Fall: 31 days

Migration length:

- Min: 12.7 mi (20.4 km)
- Mean: 45.7 mi (73.5 km)
- Max: 96.2 mi (154.8 km)

Migration area:

- 219,700 acres (88,909.4 ha) (low use; 10 percent)
- 98,021 acres (39,667.7 ha) (medium use; 10–20 percent)
- 52,887 acres (21,402.6 ha) (high use; > 20 percent)

Stopover area: 38,564 acres (15,606.3 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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Data analyst:

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- Scott Bergen, Sr. 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, *in* Meints, D.R.: Boise, Idaho, Idaho Department of Fish and Game.
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game.

Photograph from Rick Ward.

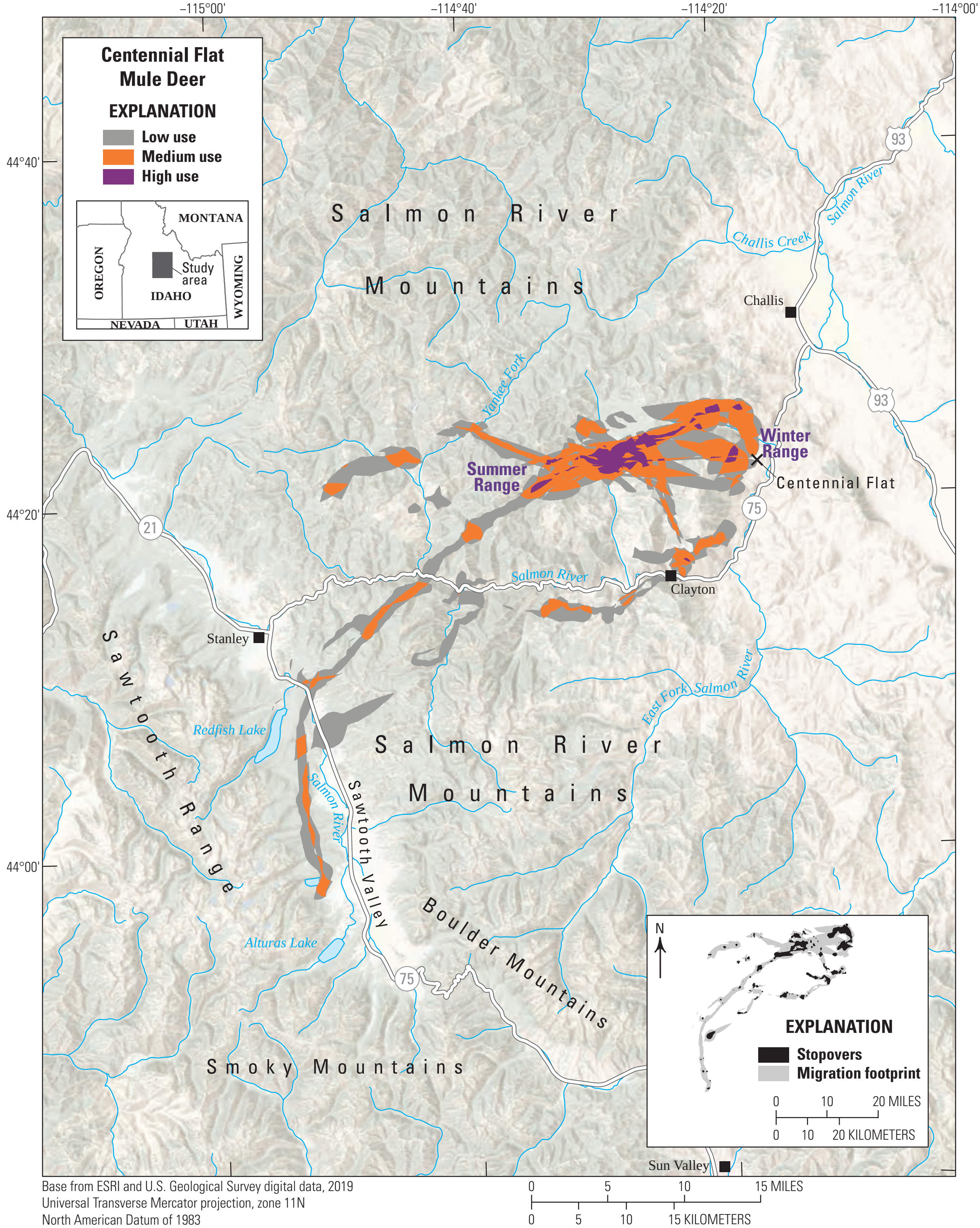

Figure 8. Migration routes and stopovers of the Centennial Flat mule deer herd.

Idaho | Mule Deer

Centennial Flat Mule Deer Migration Routes

Centennial Flat mule deer inhabit the foothills southwest of Challis, adjacent to the Salmon River in winter (fig. 8). After the snow melts, mule deer migrate to the southwest. The western migration crosses rural areas of the Salmon River Mountains, with some deer traveling through the Sawtooth Valley to summer range in the Sawtooth Mountains. On average, Centennial Flat mule deer migrate more than 30 mi (48 km) between summer and winter ranges. The wintering population of deer used for this analysis is approximately 3,370.

Animal Capture and Data Collection

Sample size: 21 adult female mule deer
Mean relocation frequency: ~13 hours
Project duration: May 27, 2003–December 3, 2018

Data Analysis

Migration and stopover analysis: Brownian bridge (Sawyer and others 2009b) and Fixed Motion Variance movement models (see further description of methods in appendix)

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

Models derived from:

- Migration: 35 sequences from 21 individuals (22 spring sequences, 13 fall sequences)

Migration and Stopover Summary

Migration start and end date (median):

- Spring: May 19 to June 1
- Fall: October 11 to November 3

Days migrating (mean):

- Spring: 14 days
- Fall: 23 days

Migration length:

- Min: 5.6 mi (9.0 km)
- Mean: 32.9 mi (52.9 km)
- Max: 51.2 mi (82.4 km)

Migration area:

- 89,491 acres (36,215.7 ha) (low use; 10 percent)
- 37,129 acres (15,025.6 ha) (medium use; 10–20 percent)
- 5,644 acres (2,284.0 ha) (high use; > 20 percent)

Stopover area: 22,286 acres (9,018.8 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
- Jessie Shallow (jessie.shallow@idfg.idaho.gov), Regional Wildlife Biologist, Idaho Department of Fish and Game

Data analyst:

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- Scott Bergen, Sr. 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, *in* Meints, D.R., Boise, Idaho, Idaho Department of Fish and Game.
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game.

Photograph from Idaho Department of Fish and Game.

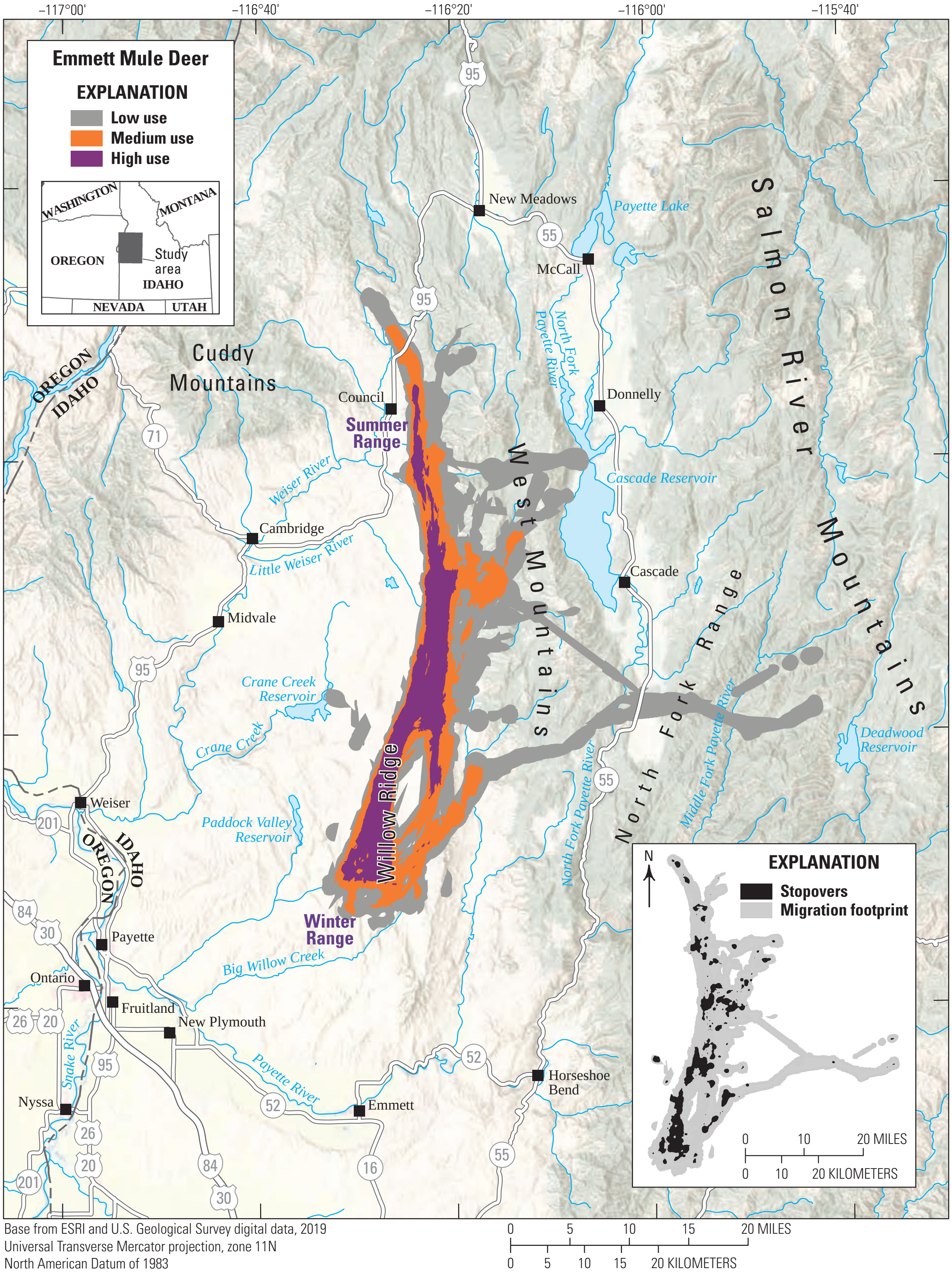

Figure 9. Migration routes and stopovers of the Emmett mule deer herd.

Idaho | Mule Deer

Emmett Mule Deer Migration Routes

Emmett mule deer winter on a mix of private and public land northeast of the Payette and Emmett, Idaho, in the vicinity of the Paddock Valley Reservoir. Repeated fires have left winter range in relatively poor condition, with a significant presence of annual grasses and noxious weeds (fig. 9). The majority of these mule deer migrate northward to summer on public land west of Cascade Reservoir. A small segment of the herd migrates eastward. Deer that do summer east of the North Fork of the Payette River and the Cascade Reservoir must cross State Highway 55. On average, Emmett mule deer migrate more than 42 mi (68 km) between summer and winter ranges. The Emmett mule deer wintering population is estimated at 24,000 mule deer.

Animal Capture and Data Collection

Sample size: 60 adult female mule deer
Mean relocation frequency: ~21 hours
Project duration: March 16, 2003–December 28, 2018

Data Analysis

Migration and stopover analysis: Brownian bridge (Sawyer and others 2009b) and Fixed Motion Variance movement models (see further description of methods in appendix)

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

Models derived from:

- Migration: 146 sequences from 60 individuals (85 spring sequences, 61 fall sequences)

Migration and Stopover Summary

Migration start and end date (median):

- Spring: March 25 to May 2
- Fall: October 17 to November 1

Days migrating (mean):

- Spring: 31 days
- Fall: 20 days

Migration length:

- Min: 12.8 mi (20.6 km)
- Mean: 42.0 mi (67.6 km)
- Max: 85.8 mi (138.1 km)

Migration area:

- 280,092 acres (113,349.2 ha) (low use; 10 percent)
- 117,332 acres (47,482.6 ha) (medium use; 10–20 percent)
- 52,247 acres (21,143.6 ha) (high use; > 20 percent)

Stopover area: 51,224 acres (20,729.6 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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Data analyst:

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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, *in* Meints, D.R.: Boise, Idaho, Idaho Department of Fish and Game.
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game.

Photograph from Rick Ward.

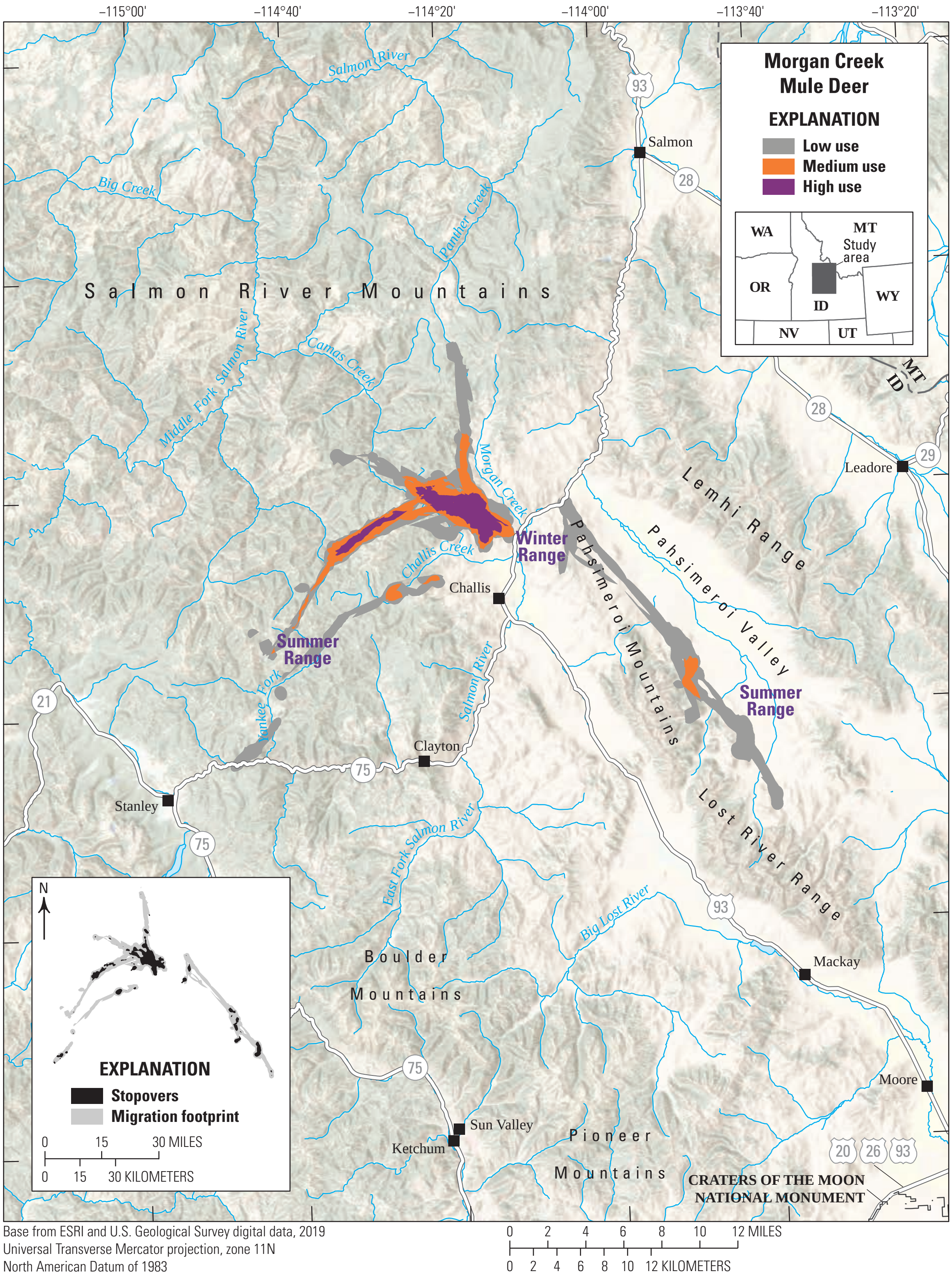

Figure 10. Migration routes and stopovers of the Morgan Creek mule deer herd.

Idaho | Mule Deer

Morgan Creek Mule Deer Migration Routes

Morgan Creek mule deer inhabit the foothills north of Challis in winter (fig. 10). After the snow melts, some mule deer migrate to the east (Pahsimeroi Valley), while the majority migrate to the west. The western migration fans out across rural and wilderness areas, whereas the eastern migration mainly follows the Pahsimeroi Mountains. On average, Morgan Creek mule deer migrate 25 mi (40 km) between summer and winter ranges, with more extensive migrations occurring to the west that reach more than 85 mi (137 km). The Morgan Creek population of wintering mule deer is approximately 2,650.

Animal Capture and Data Collection

Sample size: 39 adult female mule deer
Mean relocation frequency: ~17 hours
Project duration: May 13, 2012–December 31, 2018

Data Analysis

Migration and stopover analysis: Brownian bridge (Sawyer and others 2009b) and Fixed Motion Variance movement models (see further description of methods in appendix).

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

Models derived from:

- Migration: 114 sequences from 39 individuals (66 spring sequences, 48 fall sequences)

Migration and Stopover Summary

Migration start and end date (median):

- Spring: April 30 to May 16
- Fall: October 29 to December 23

Days migrating (mean):

- Spring: 16 days
- Fall: 55 days

Migration length:

- Min: 5.5 mi (8.9 km)
- Mean: 25.4 mi (40.9 km)
- Max: 87.1 mi (140.2 km)

Migration area:

- 147,132 acres (59542.2 ha) (low use; 10 percent)
- 44,624 acres (18058.7 ha) (medium use; 10–20 percent)
- 16,897 acres (6,838.0 ha) (high use; > 20 percent)

Stopover area: 34,660 acres (14,026.4 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
- Jessie Shallow (jessie.shallow@idfg.idaho.gov), Regional Wildlife Biologist, Idaho Department of Fish and Game

Data analyst:

- Jodi Berg, Sr. Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming
- Scott Bergen, Sr. 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, *in* Meints, D.R.: Boise, Idaho, Idaho Department of Fish and Game.
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game.

Photograph from Idaho Department of Fish and Game.

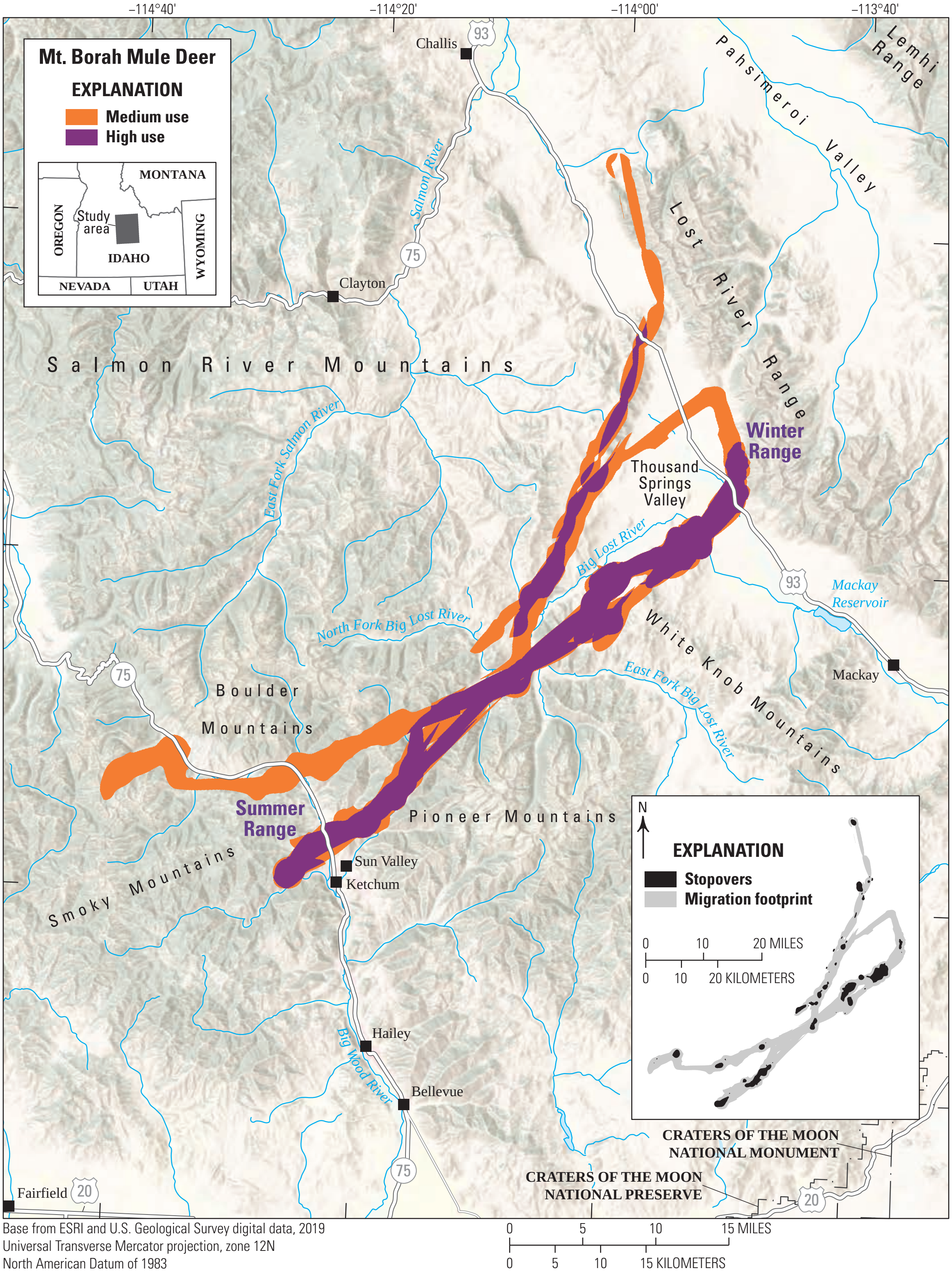

Figure 11. Migration routes and stopovers of the Mt. Borah mule deer herd.

Idaho | Mule Deer

Mt. Borah Mule Deer Migration Routes

The Mt. Borah mule deer winter on the western flats at the base of the Lost River Range between the Vance Canyon area in the south and Lime Creek in the north (fig. 11). Access to winter habitat—which is shared by elk, pronghorn, and bighorn sheep—is limited by steep, rocky slopes and deep snow. As snow subsides in the spring, mule deer migrate to the west and converge past Thousand Springs Valley, following the Big Lost River drainage to reach their summer range north of Ketchum in the Smoky Mountains. On average, these mule deer migrate nearly 50 mi (80 km), and some migrate as far as 73 mi (117 km). Continued improvements to Trail Creek Road and associated infrastructure development could result in deer mortalities due to increased traffic, because the migration route follows the roadway quite closely. In addition, human development, particularly in GMU 49, could prove detrimental for migrating and summering mule deer. The Mt. Borah population consists of roughly 400–500 individuals (based on aerial surveys in 2010).

Animal Capture and Data Collection

Sample size: 12 adult female mule deer
Mean relocation frequency: ~16 hours
Project duration: April 2017–December 2018

Data Analysis

Migration and stopover analysis: Fixed Motion Variance movement models (see further description of methods in appendix)

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

Models derived from:

- Migration: 27 sequences from 12 individuals (18 spring sequences, 9 fall sequences)

Migration and Stopover Summary

Migration start and end date (median):

- Spring: April 17 to May 27
- Fall: November 22 to December 23

Days migrating (mean):

- Spring: 39 days
- Fall: 31 days

Migration length:

- Min: 27.8 mi (44.7 km)
- Mean: 48.9 mi (78.7 km)
- Max: 73.4 mi (118.1 km)

Migration area:

- 130,831 acres (52,945.4 ha) (medium use; 10–20 percent)
- 67,086 acres (27,148.7 ha) (high use; > 20 percent)

Stopover area: 21,745 acres (8799.9 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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Data analyst:

- Jodi Berg, Sr. Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming
- Scott Bergen, Sr. 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, *in* Meints, D.R.: Boise, Idaho, Idaho Department of Fish and Game.
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game.

Photograph from Idaho Department of Fish and Game.

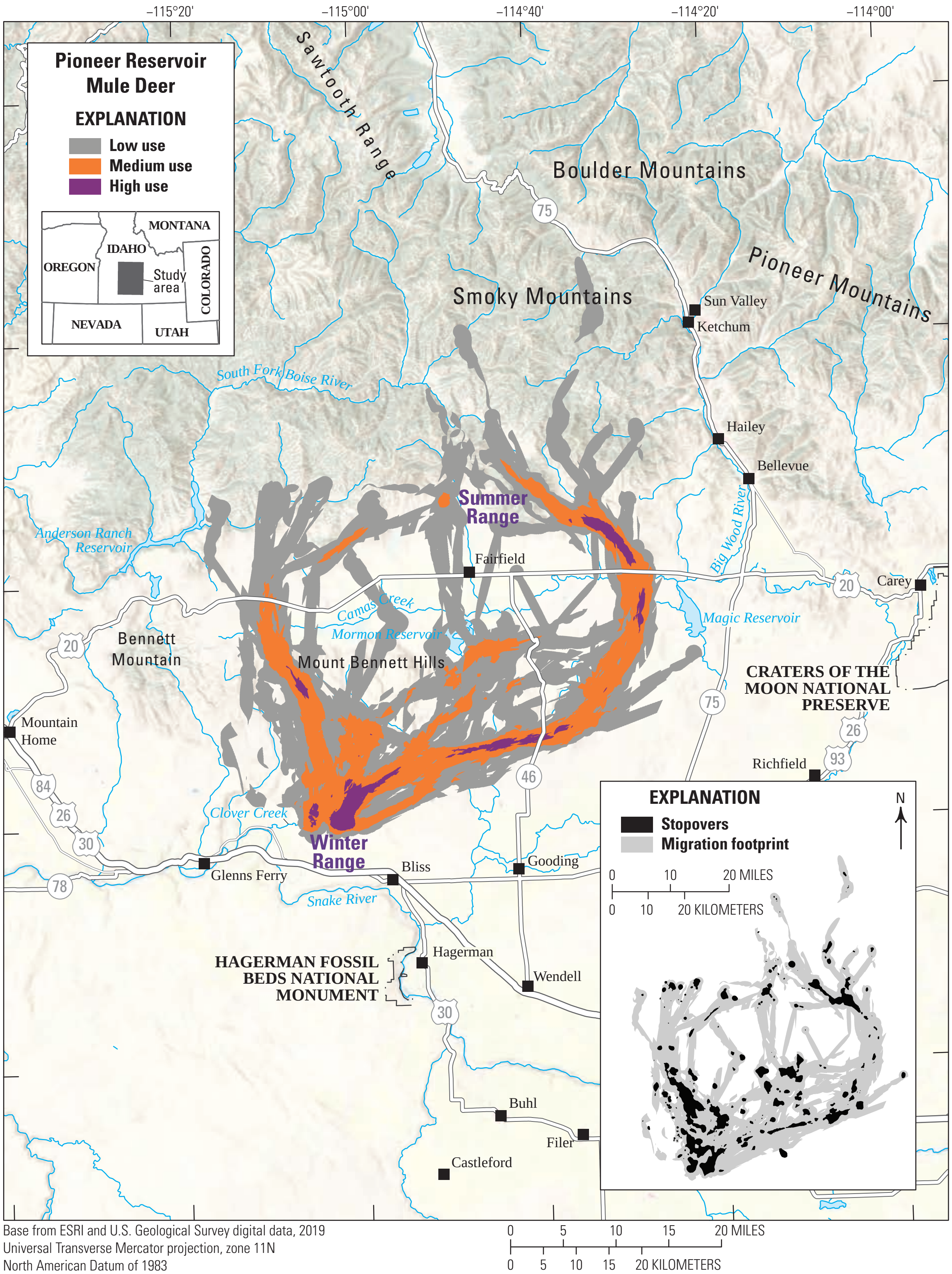

Figure 12. Migration routes and stopovers of the Pioneer Reservoir mule deer herd.

Idaho | Mule Deer

Pioneer Reservoir Mule Deer Migration Routes

Pioneer Reservoir mule deer winter east of Mountain Home, in vicinity of the junction between Clover Creek and the Snake River (fig. 12). They migrate north-northeast past Anderson Ranch and past Mormon and Magic Reservoirs to summer west of Hailey and Ketchum. On average, these mule deer migrate over 46 mi (74 km) between summer and winter ranges. The population of wintering mule deer in the greater Smoky-Bennett Population Management Unit (including the Bennett-Teapot Dome population) was estimated at 16,358 in 2018. Seasonal movement pathways of the Pioneer Reservoir mule deer may be influenced by energy development and transportation infrastructure, whereas winter habitats are changing due to fire and the proliferation of exotic annual grasses.

Animal Capture and Data Collection

Sample size: 66 adult female mule deer
Mean relocation frequency: ~17 hours
Project duration: April 8, 2012–December 15, 2018

Data Analysis

Migration and stopover analysis: Brownian bridge (Sawyer and others 2009b) and Fixed Motion

Variance movement models (see further description of methods in appendix)

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

Models derived from:

- Migration: 153 sequences from 66 individuals (93 spring sequences, 60 fall sequences)

Migration and Stopover Summary

Migration start and end date (median):

- Spring: April 4 to May 3
- Fall: October 10 to October 27

Days migrating (mean):

- Spring: 26 days
- Fall: 24 days

Migration length:

- Min: 13.9 mi (22.4 km)
- Mean: 46.7 mi (75.2 km)
- Max: 125.3 mi (201.7 km)

Migration area:

- 536,079 acres (216,943.5 ha) (low use; 10 percent)
- 142,908 acres (57,832.8 ha) (medium use; 10–20 percent)
- 17,446 acres (7,060.1 ha) (high use; >20 percent)

Stopover area: 84,410 acres (34,159.5 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:

- Jodi Berg, Sr. 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, *in* Meints, D.R.: Boise, Idaho, Idaho Department of Fish and Game.
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game.

Photograph from John Stolzman.

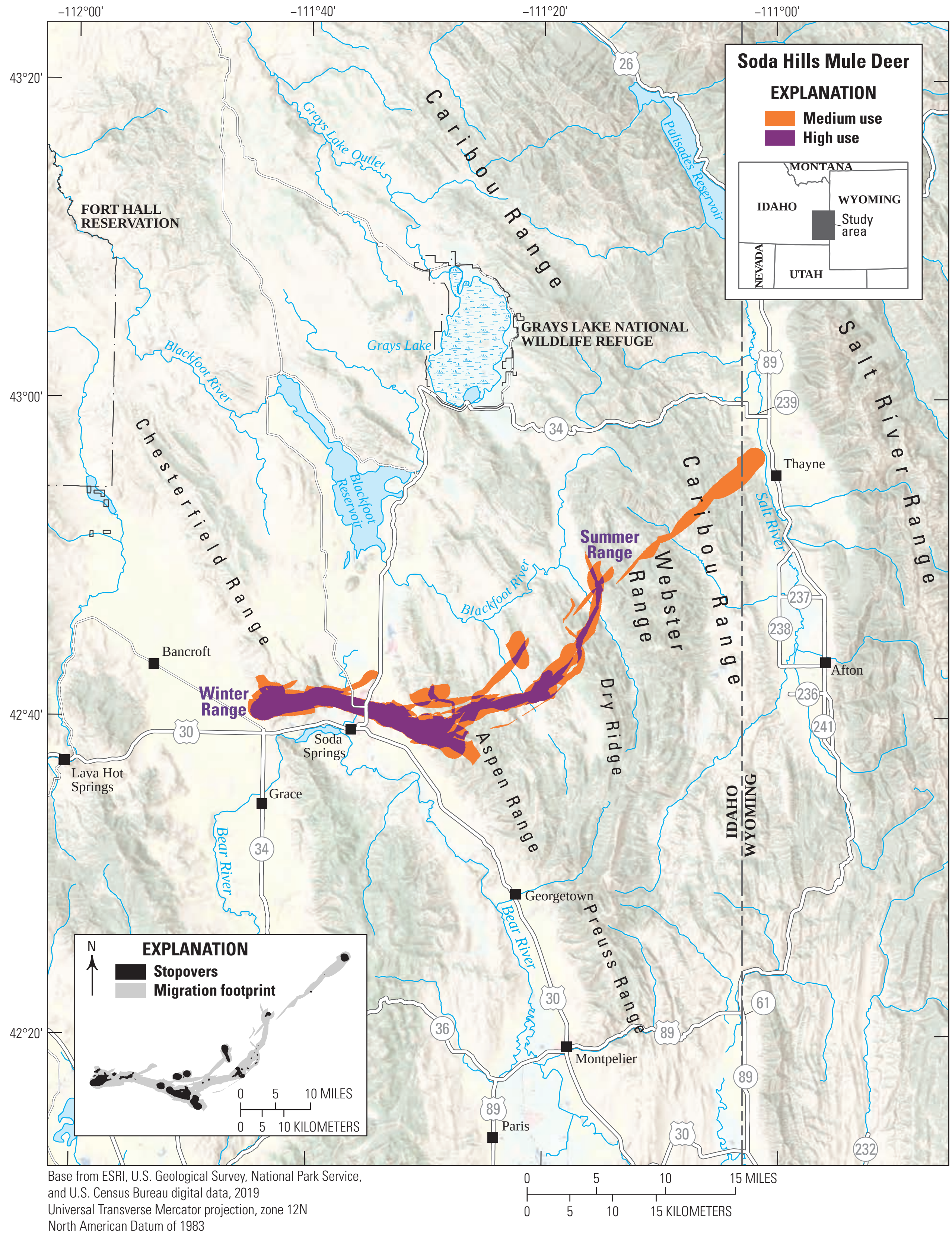

Figure 13. Migration routes and stopovers of the Soda Hills mule deer herd.

Idaho | Mule Deer

Soda Hills Mule Deer Migration Routes

Soda Hills mule deer winter north of Soda Springs (fig. 13). These mule deer migrate northeast to summer ranges in the Webster or Caribou Ranges along the Idaho–Wyoming border. On average, Soda Hills mule deer migrate 32 mi (51 km) between summer and winter ranges. The Soda Hills wintering population numbers 3,500–5,000 animals. Seasonal movement pathways for mule deer wintering in the Soda Hills may be influenced by transportation and development infrastructure, whereas summer habitats are changing due to direct loss of habitat from mineral extraction and loss of important aspen communities.

Animal Capture and Data Collection

Sample size: 15 adult female mule deer
Relocation frequency: ~30 hours
Project duration: April 24, 2013–December 4, 2018

Data Analysis

Migration and stopover analysis: Brownian bridge (Sawyer and others 2009b) and Fixed Motion Variance movement models (see further description of methods in appendix)

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

Models derived from:

- Migration: 23 sequences from 15 individuals (15 spring sequences, 8 fall sequences)

Migration and Stopover Summary

Migration start and end date (median):

- Spring: April 27 to May 15
- Fall: October 15 to October 30

Days migrating (mean):

- Spring: 25 days
- Fall: 32 days

Migration length:

- Min: 13.3 mi (21.4 km)
- Mean: 32.1 mi (51.7 km)
- Max: 47.3 mi (76.1 km)

Migration area:

- 50,900 acres (20,598.5 ha) (medium use; 10–20 percent)
- 24,129 acres (9,764.7 ha) (high use; >20 percent)

Stopover area: 12,235 acres (4,951.3 ha)

Other Information

Project contacts:

- Mark Hurley (mark.hurley@idfg.idaho.gov), Wildlife Research Supervisor, Idaho Department of Fish and Game
- Zach Lockyer (zach.lockyer@idfh.idaho.gov), Regional Wildlife Manager, Idaho Department of Fish and Game

Data analyst:

- Jodi Berg, Sr. 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, *in* Meints, D.R.: Boise, Idaho, Idaho Department of Fish and Game.
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game.

Photograph from Idaho Department of Fish and Game.

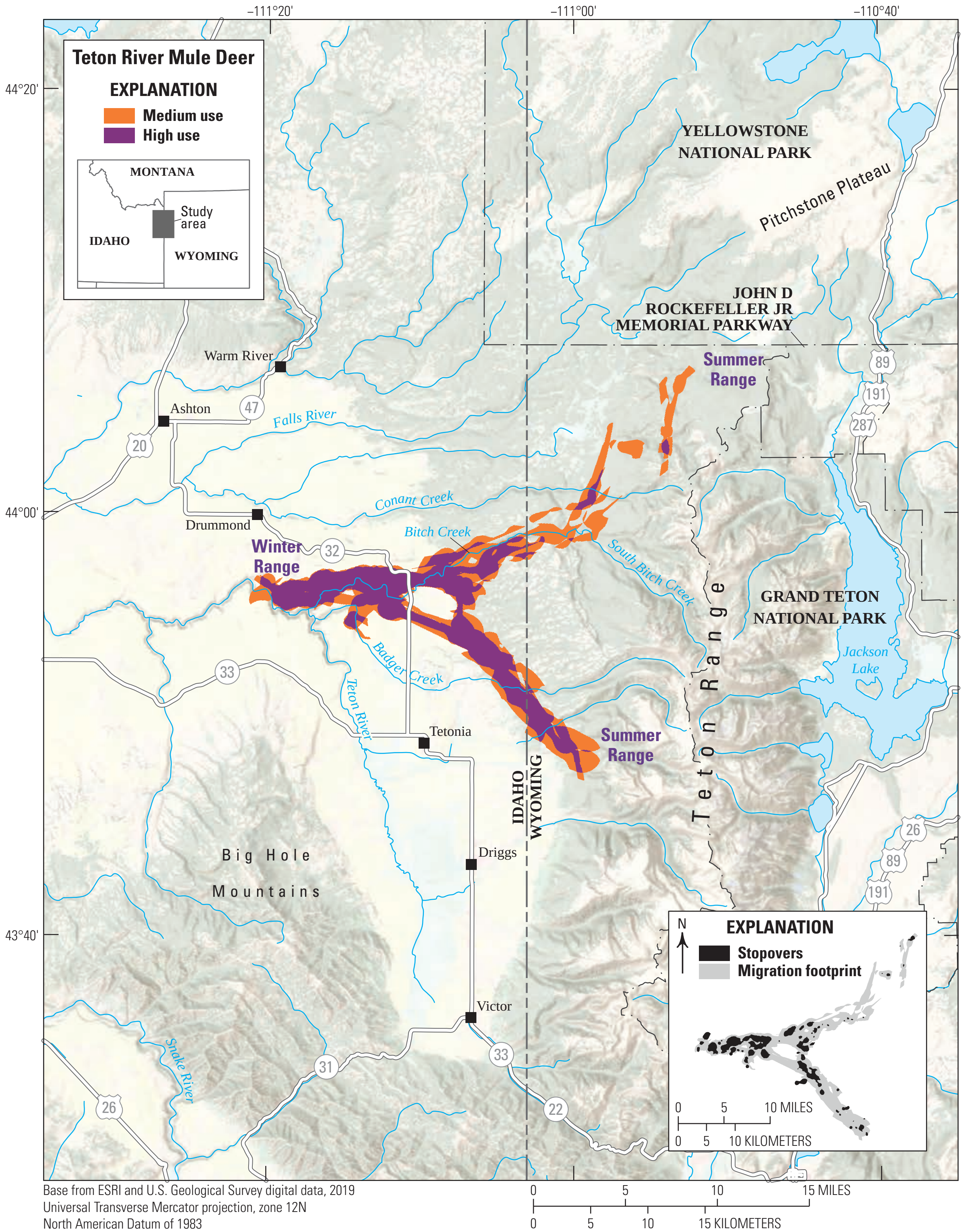

Figure 14. Migration routes and stopovers of the Teton River mule deer herd.

Idaho | Mule Deer

Teton River Mule Deer Migration Routes

Teton River mule deer winter adjacent to the Teton River in eastern Idaho (fig. 14). Due to limited quality and quantity of winter habitat, the 1,000–2,500 individuals within this population are greatly influenced by winter severity. The deer—and especially the fawns—experience dramatic swings in productivity and mortality. Teton River mule deer migrate eastward across the Idaho-Wyoming border to two areas west of the Teton Range: the northern summer range southwest of Pitchstone Plateau and the southern summer range in the western foothills of the Teton Range. On average, Teton River mule deer migrate 25 mi (40 km) between summer and winter ranges, with the longest migration spanning more than 70 mi (113 km). Challenges to Teton River deer migration include human activity related to residential subdivision development and recreation in rural residential areas northeast of Driggs.

Animal Capture and Data Collection

Sample size: 15 adult female mule deer
Mean relocation frequency: ~3 hours
Project duration: April 2018–December 2018

Data Analysis

Migration and stopover analysis: Brownian bridge (Sawyer and others 2009b) and Fixed Motion Variance movement models (see further description of methods in appendix)

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

Models derived from:

- Migration: 30 sequences from 15 individuals (15 spring sequences, 15 fall sequences)

Migration and Stopover Summary

Migration start and end date (median):

- Spring: May 4 to May 16
- Fall: November 7 to November 13

Days migrating (mean):

- Spring: 19 days
- Fall: 14 days

Migration length:

- Min: 8.2 mi (13.2 km)
- Mean: 25.4 mi (40.9 km)
- Max: 70.1 mi (112.8 km)

Migration area:

- 42,785 acres (17,314.5 ha) (medium use; 10–20 percent)
- 23,607 acres (9,553.4 ha) (high use; >20 percent)

Stopover area: 10,544 acres (4,267 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
- Sarah Dewey (sarah_dewey@nps.gov), Wildlife Biologist, Grand Teton National Park

Data analyst:

- Jodi Berg, Sr. 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, *in* Meints, D.R.: Boise, Idaho, Idaho Department of Fish and Game.
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game.

Photograph from Idaho Department of Fish and Game.

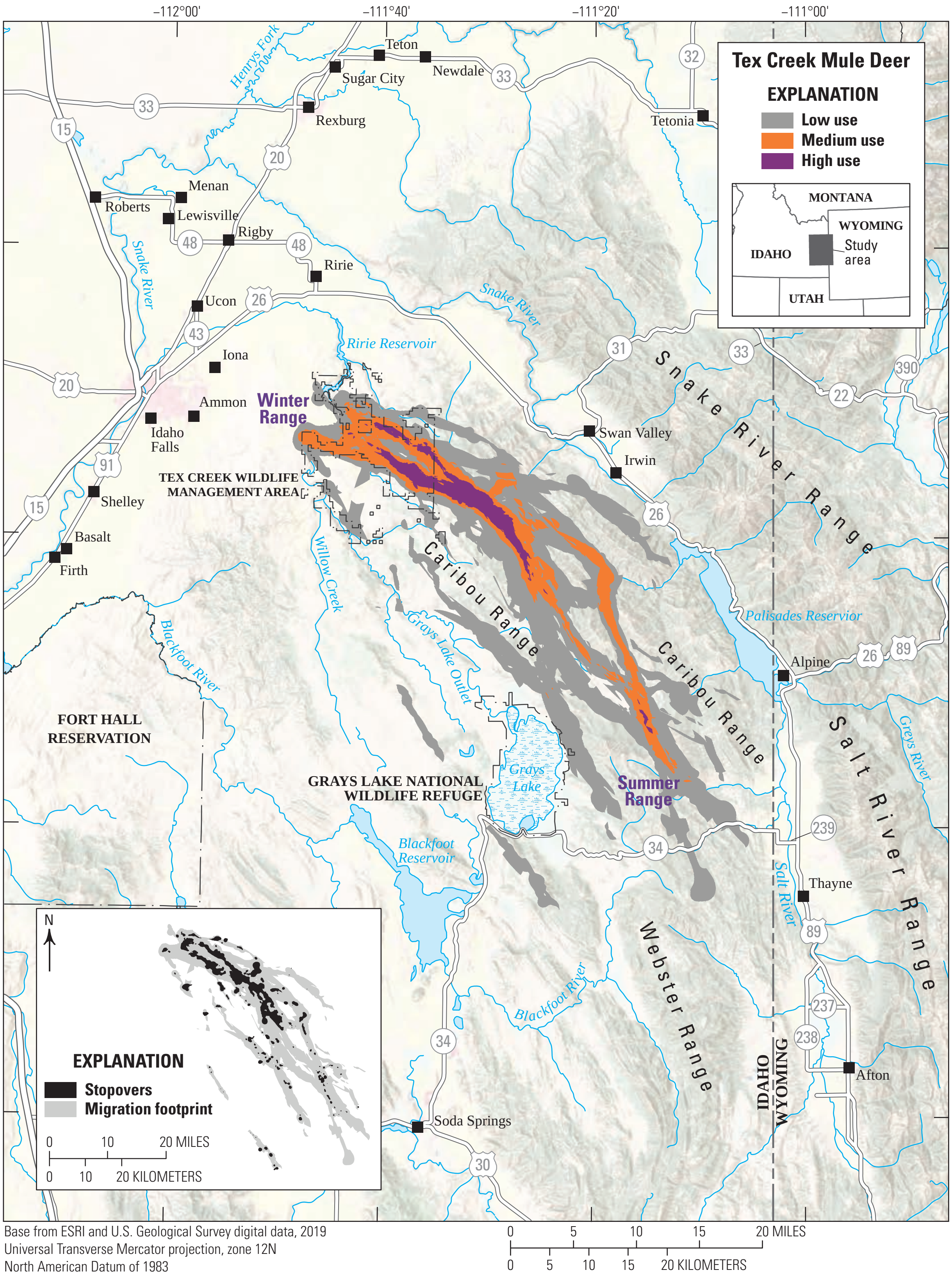

Figure 15. Migration routes and stopovers of the Tex Creek mule deer herd.

Idaho | Mule Deer

Tex Creek Mule Deer Migration Routes

Tex Creek mule deer winter in the valleys surrounding the Ririe Reservoir (fig. 15). These valleys include Tex Creek, Willow Creek, and Grays Lake Outlet. This habitat is varied, consisting of steep, rocky canyon walls, small drainages, and open flats. Mule deer migrate across the Caribou Range to summer ranges spread across GMUs 66 and 66A, with some deer extending southward into GMU 76. On average, Tex Creek mule deer migrate 35 mi (56 km), with the longest migration recorded at 65 mi (105 km). The wintering herd historically numbered approximately 4,500 individuals, but the Henry's Creek fire in 2016 burned 52,000 acres (21,044 hectares) of habitat used by 80 percent of the wintering deer. The fire was followed by heavy snow accumulations in winter. The combination dramatically altered the 2016 winter range and impacted subsequent deer densities. The 2019 population estimate indicated a 40 percent population decline in the northern portion of Caribou Data Analysis Unit (DAU) and a 75 percent decline within the fire footprint. The impacts of the fire, along with human recreation (particularly motorized vehicles), changing land management, and human development, continues to challenge this mule deer herd.

Animal Capture and Data Collection

Sample size: 63 adult female mule deer
Mean relocation frequency: ~13 hours
Project duration: March 16, 2007–December 23, 2018

Data Analysis

Migration and stopover analysis: Brownian bridge (Sawyer and others 2009b) and Fixed Motion Variance movement models (see further description of methods in Appendix 1)

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

Models derived from:

- Migration: 108 sequences from 63 individuals (76 spring sequences, 32 fall sequences)

Migration and Stopover Summary

Migration start and end date (median):

- Spring: April 18 to May 9
- Fall: November 3 to December 20

Days migrating (mean):

- Spring: 20 days
- Fall: 41 days

Migration length:

- Min: 2.3 mi (3.7 km)
- Mean: 35.2 mi (56.6 km)
- Max: 64.9 mi (104.4 km)

Migration area:

- 215,233 acres (87,101.7 ha) (low use; 2 individuals—10 percent)
- 53,617 acres (21,698.0 ha) (medium use; 10–20 percent)
- 12,781 acres (5,172.3 ha) (high use; >20 percent)

Stopover area: 39,970 acres (16,175.3 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 analyst:

- Jodi Berg, Sr. Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming
- Scott Bergen, Sr. 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, in Meints, D.R.: Boise, Idaho, Idaho Department of Fish and Game.
- Hurley, M.A., and Roberts, S., 2019, F16AF00908 statewide wildlife research final performance report: Boise, Idaho, Idaho Department of Fish and Game.

Photograph from Idaho Department of Fish and Game.

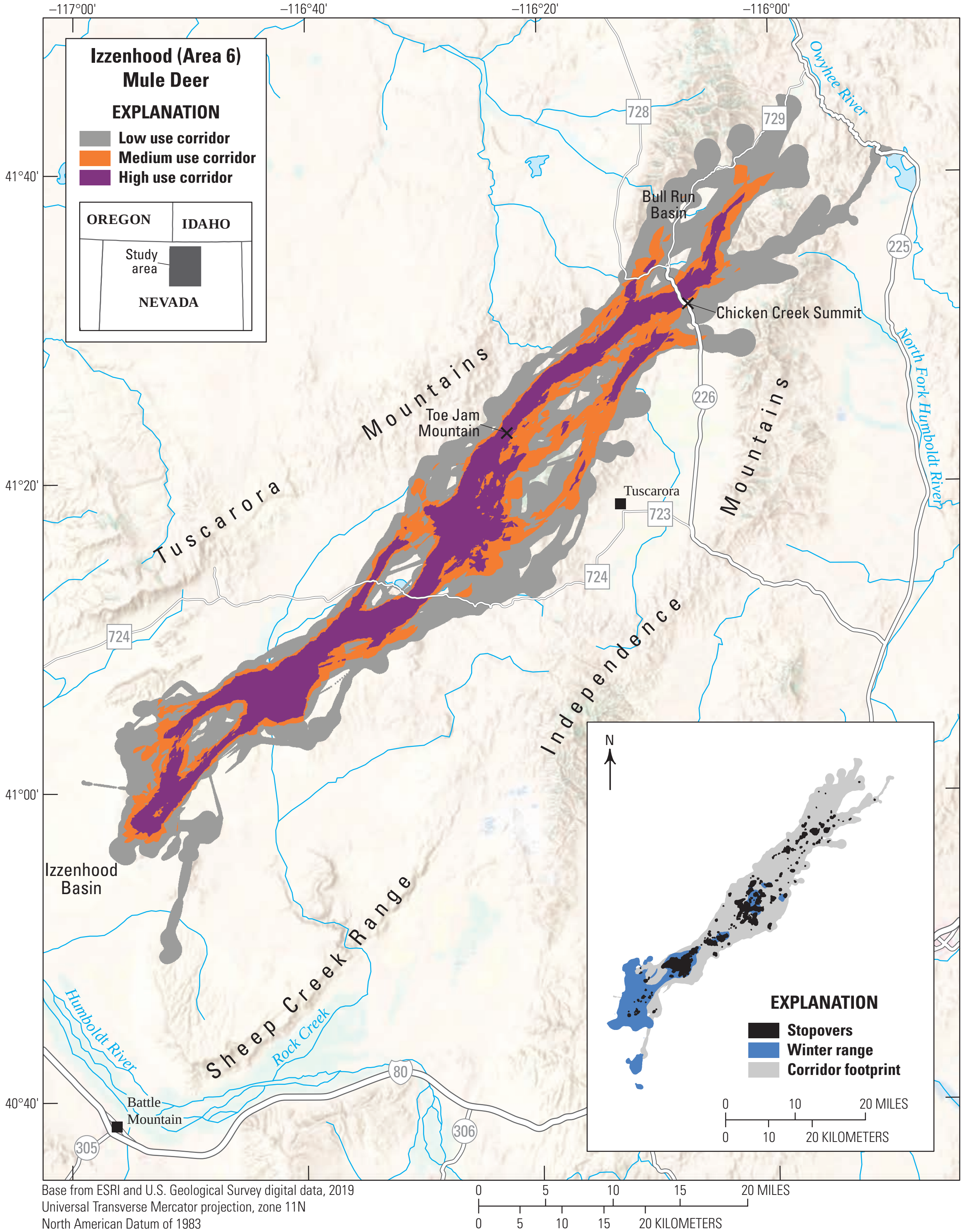

Figure 16. Migration corridors, stopovers, and winter ranges of the Izzenhood mule deer population.

Nevada | Mule Deer

Izzenhood Mule Deer Migration Corridors

Mule deer in the Izzenhood population are part of the larger Area 6 mule deer herd. They primarily reside on winter ranges in the Izzenhood Basin and upper Rock Creek drainages (fig. 16). From their winter range, mule deer in this population migrate approximately 70 mi (113 km) to summer ranges in the northern Independence Mountains and Bull Run Basin. Some of the most important stopover areas are located near upper Rock Creek, Toe Jam Mountain, and Chicken Creek Summit. Challenges faced by this population include historic wildfires on winter range, conversion of native shrub habitats to exotic annual grasses, and lower forage production in some stopover sites.

Animal Capture and Data Collection

Sample size: 35 adult female mule deer
Relocation frequency: 1–25 hours
Project duration: 2015–2019

Data Analysis

Corridor, stopover, and winter range analysis: Brownian bridge movement models (Sawyer and others 2009b)
Delineation of migration periods: Net Squared Displacement (Bunnefeld and others 2011)
Models derived from:

- Migration: 87 sequences from 35 individuals
- Winter: 69 sequences from 35 individuals

Corridor and Stopover Summary

Migration start and end date (median):
Spring: March 17 to April 23
Fall: November 12 to December 10
Days migrating (mean):

- Spring: 36 days
- Fall: 41 days

Migration length:

- Min: 25 mi (40.2 km)
- Mean: 59 mi (95.0 km)
- Max: 83 mi (133.6 km)

Migration area:

- 371,557 acres (150,363.8 ha) (low use)
- 168,278 acres (68,099.7 ha) (medium use)
- 91,582 acres (37,062.0 ha) (high use)

Stopover area: 38,391 acres (15,536.3 ha)

Winter Range Summary

Winter start and end date (median):

- December 15 to March 1

Winter length (mean): 75 days
Winter range (30 percent contour) area: 109,088 acres (44,146 hectares)

Other Information

Project contacts:

- Cody Schroeder (cschroeder@ndow.org), Wildlife Staff Specialist, Nevada Department of Wildlife
- Matt Jeffress (mjeffress@ndow.org), Game Biologist, Nevada Department of Wildlife
- Travis Allen (tallen@ndow.org), Game Biologist, Nevada Department of Wildlife

Data analyst:

- Hall Sawyer, Wildlife Biologist, WEST, Inc.

Photograph from Matt Jeffress.

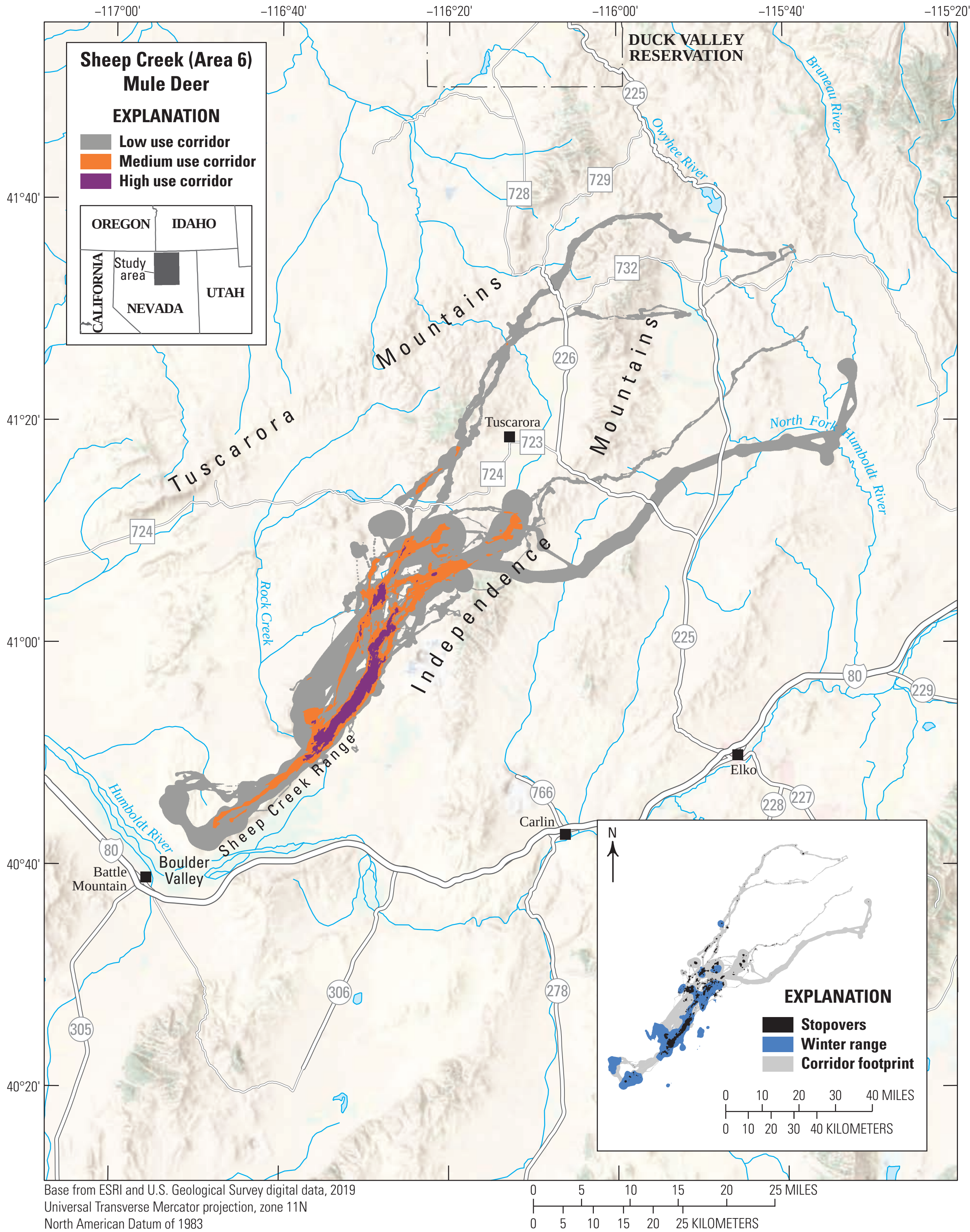

Figure 17. Migration corridors, stopovers, and winter ranges of the Sheep Creek mule deer population.

Nevada | Mule Deer

Sheep Creek Mule Deer Migration Corridors

Mule deer in the Sheep Creek population are part of the larger Area 6 herd. The primary winter range of this population is located along the eastern flank of the Sheep Creek Range, Independence Mountains and the west side of Boulder Valley (fig. 17). Most deer migrate approximately 30 mi (48 km) from winter ranges to summer ranges on the west side of the Tuscarora Mountains. However, some deer in this population migrate much farther—approximately 80 mi (129 km)—and connect with mule deer that summer east of the Humboldt River. This deer herd faces several challenges, including migration routes that pass through increased mineral extraction activities northwest of Carlin, invasion of exotic annual grasses on winter range, increased wildfires on winter range, and deteriorated range conditions on many stopover sites and winter range.

Animal Capture and Data Collection

Sample size: 36 adult female mule deer
Relocation frequency: 1–25 hours
Project duration: 2012–2019

Data Analysis

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

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

Models derived from:

- Migration: 68 sequences from 36 individuals
- Winter: 58 sequences from 34 individuals

Corridor and Stopover Summary

Migration start and end date (median):

- Spring: March 22 to April 9
- Fall: December 7 to December 18

Days migrating (mean):

- Spring: 16 days
- Fall: 11 days

Migration length:

- Min: 13 mi (20.9 km)
- Mean: 37 mi (59.5 km)
- Max: 98 mi (157.7 km)

Migration area:

- 284,394 acres (115,090.2 ha) (low use)
- 54,122 acres (21,902.4 ha) (medium use)
- 13,352 acres (5403.3 ha) (high use)

Stopover area: 29,430 acres (11,090.9 ha)

Winter Range Summary

Winter start and end date (median):

- December 15 to March 1

Winter length (mean): 75 days

Winter range (30 percent contour) area: 108,973 acres (44,099.8 ha)

Other Information

Project contacts:

- Cody Schroeder (cschroeder@ndow.org), Wildlife Staff Specialist, Nevada Department of Wildlife
- Matt Jeffress (mjeffress@ndow.org), Game Biologist, Nevada Department of Wildlife
- Travis Allen (tallen@ndow.org), Game Biologist, Nevada Department of Wildlife

Data analyst:

- Hall Sawyer, Wildlife Biologist, WEST, Inc.

Photograph from Tim Torrell.

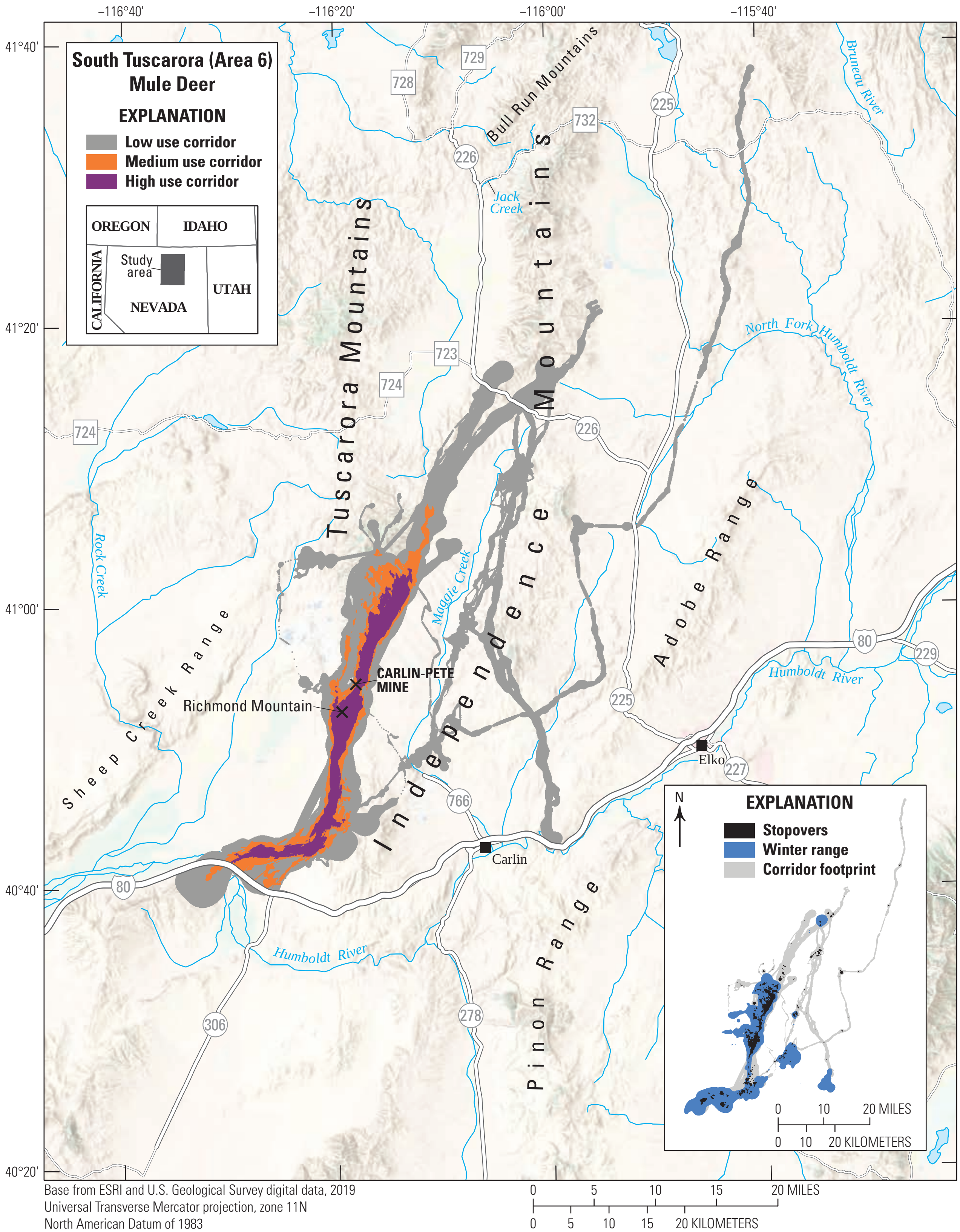

Figure 18. Migration corridors, stopovers, and winter ranges of the South Tuscarora mule deer population.

Nevada | Mule Deer

South Tuscarora Mule Deer Migration Corridors

Mule deer in the South Tuscarora population reside in the most southern and eastern portion of the larger Area 6 herd. The winter range for this population is located along the eastern slopes of the Tuscarora Mountains and west of Maggie Creek (fig. 18). The spring migration route for this deer herd traverses north along the toe slopes of the Tuscarora Mountains on the east side and narrows to approximately 600 meters (m; 1,969 feet [ft]) at one pinch point near the Carlin-Pete Mine area. The migration route generally spans 30 mi (48 km) to the northeast, with summer ranges at higher elevations in the northern Tuscarora Mountains. Important stopover areas include Richmond Mountain and Jack Creek on the east side of the Tuscarora Mountains. Challenges to this deer herd include constrictions in the migration corridor from large-scale gold mining operations and multiple wildfires on winter ranges southwest of Carlin. Interstate traffic also causes a high rate of mortality and a network of fences are a challenge to some deer that continue to migrate south along the I-80 corridor.

Animal Capture and Data Collection

Sample size: 35 adult female mule deer
Relocation frequency: 1–25 hours
Project duration: 2012–2019

Data Analysis

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

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

Models derived from:

- Migration: 63 sequences from 31 individuals
- Winter: 60 sequences from 35 individuals

Corridor and Stopover Summary

Migration start and end date (median):

- Spring: March 14 to April 3
- Fall: December 15 to December 25

Days migrating (mean):

- Spring: 18 days
- Fall: 10 days

Migration length:

- Min: 9 mi (14.5 km)
- Mean: 34 mi (54.7 km)
- Max: 70 mi (112.7 km)

Migration area:

- 201,620 acres (81,592.7 ha) (low use)
- 44,403 acres (17,969.3 ha) (medium use)
- 22,153 acres (8,965.0 ha) (high use)

Stopover area: 20,685 acres (8,370.9 ha)

Winter Range Summary

Winter start and end date (median):

- December 15 to March 1

Winter length (mean): 75 days

Winter range (30 percent contour) area: 124,992 acres (50,582.5 ha)

Other Information

Project contacts:

- Cody Schroeder (cschroeder@ndow.org), Wildlife Staff Specialist, Nevada Department of Wildlife
- Matt Jeffress (mjeffress@ndow.org), Game Biologist, Nevada Department of Wildlife
- Travis Allen (tallen@ndow.org), Game Biologist, Nevada Department of Wildlife

Data analyst:

- Hall Sawyer, Wildlife Biologist, WEST, Inc.

Photograph from Matt Jeffress.

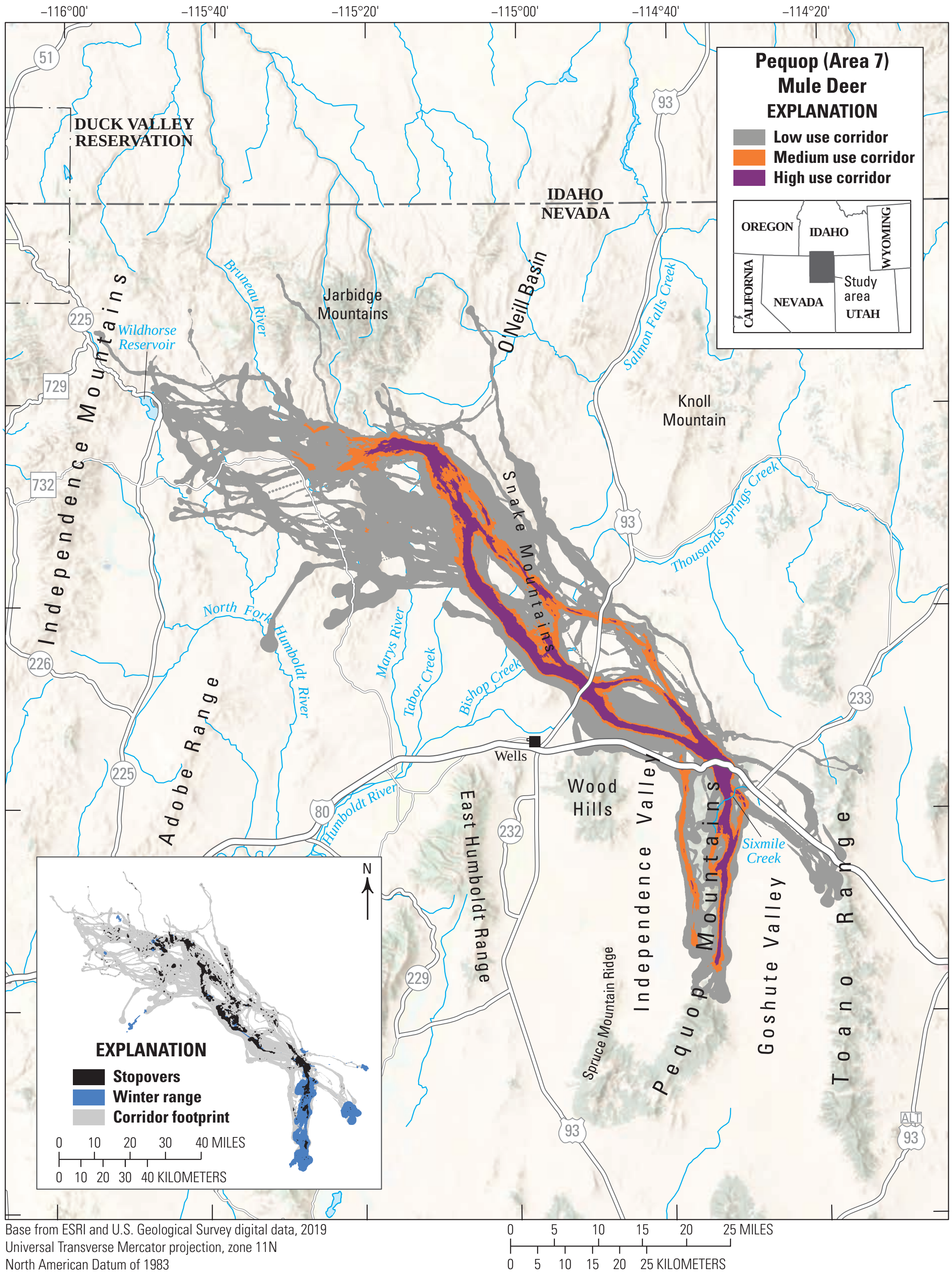

Figure 19. Migration corridors, stopovers, and winter ranges of the Pequop mule deer herd.

Nevada | Mule Deer

Pequop Mule Deer Migration Corridors

The Pequop (Area 7) mule deer population is one of Nevada's largest deer herds with an estimated population size of 11,000 in 2019. This deer herd is highly important from an economic and ecological perspective. These deer make one of the longest known deer migrations in the state, with some animals travelling more than 120 mi (193 km) one way (fig. 19). Winter range for this deer herd occurs primarily along the east side of the Pequop Mountains. The largest stopovers occur along the west side of the Snake Mountains near Tabor Creek and Bishop Creek, north and south of I-80, and in the Pequop Mountains south of Sixmile Creek. The summer range for this herd is located on the southern portion of the Jarbidge Mountains east of Wildhorse Reservoir. A subset of this population, known as the "Pequop" herd, crosses both U.S. Highway 93 and I-80 twice annually during their seasonal migrations. Several million dollars in wildlife crossing structures have been constructed to help these deer during their migration, yet they still face challenges to connectivity between winter and summer ranges, including miles of livestock fencing and a large-scale gold mine operation in close proximity to a large stopover site near Long Canyon.

Animal Capture and Data Collection

Sample size: 86 adult female mule deer
Relocation frequency: 1–25 hours
Project duration: 2011–2017

Data Analysis

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

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

Models derived from:

- Migration: 218 sequences from 79 individuals
- Winter: 193 sequences from 86 individuals

Corridor and Stopover Summary

Migration start and end date (median):

- Spring: March 15 to April 5
- Fall: October 7 to October 31

Days migrating (mean):

- Spring: 21 days
- Fall: 23 days

Migration length:

- Min: 37 mi (59.5 km)
- Mean: 77 mi (123.9 km)
- Max: 120 mi (193.1 km)

Migration area:

- 712,619 acres (288,386.7 ha) (low use)
- 153,739 acres (62,216.0 ha) (medium use)
- 70,832 acres (28,664.7 ha) (high use)

Stopover area: 73,232 acres (29,636.0 ha)

Winter Range Summary

Winter start and end date (median):

- December 15 to March 1

Winter length (mean): 75 days

Winter range (30 percent contour) area: 181,671 acres (73,519.6 ha)

Other Information

Project contacts:

- Cody Schroeder (cschroeder@ndow.org), Wildlife Staff Specialist, Nevada Department of Wildlife
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Data analyst:

- Hall Sawyer, Wildlife Biologist, WEST, Inc.

Reports and publications:

- Shoemaker, K.T., Heffelfinger, L.J., Jackson, N.J., Blum, M.E., Wasley, T., and Stewart, K.M., 2018, A machine-learning approach for extending classical wildlife resource selection analyses: Ecology and Evolution, v. 8, no. 6, p. 3556–3569.[Also available at https://doi.org/10.1002/ece3.3936.]
- Simpson, N.O., Stewart, K.M., Schroeder, C., Cox, M., Huebner, K., and Wasley, T., 2016, Overpasses and underpasses: Effectiveness of crossing structures for migratory ungulates: The Journal of Wildlife Management, v. 80, no. 8, p. 1370–1378.

Photograph from Kari Huebner.

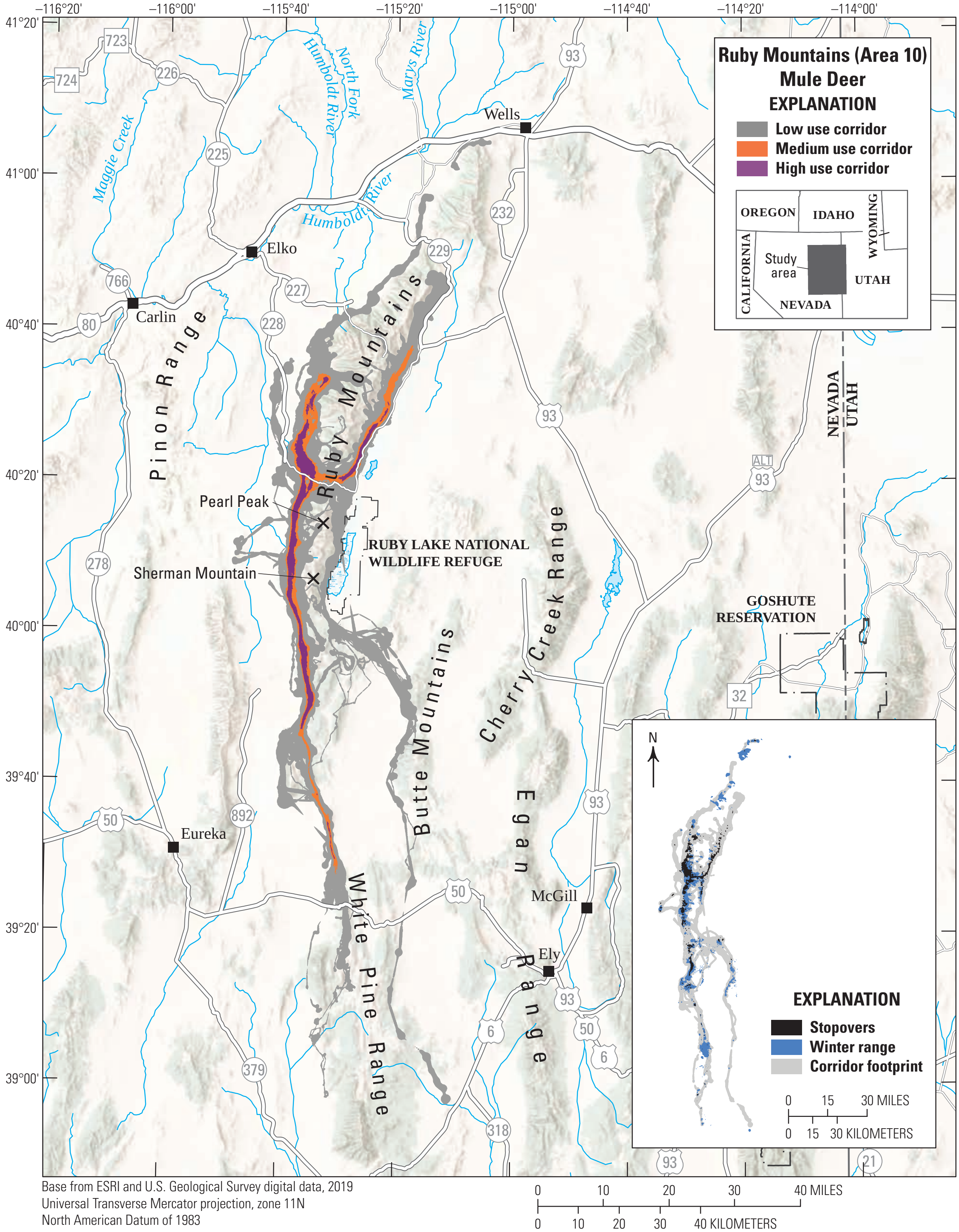


Figure 20. Migration corridors, stopovers, and winter ranges of the Ruby Mountains mule deer herd.

Nevada | Mule Deer

Ruby Mountains Mule Deer Migration Corridors

The Ruby Mountains (Area 10) mule deer population is one of the state's largest deer herds, accounting for nearly 20 percent of mule deer in Nevada. This herd is comprised of several subpopulations that occupy the Ruby Mountains and tend to migrate long distances—40 to 100 mi (64 to 161 km)—between summer and winter ranges. Several key stopover areas occur within this herd's migration corridor (fig. 20). The largest stopover areas are on the west side of the Ruby Mountains north and south of Nevada State Route 228. The expansive winter range spans approximately 120 mi (193 km) along the lower elevations of the Ruby Mountains from I-80 south to U.S. Highway 50. Some migrations extend even farther south in extreme winters, while some animals may continue migrating another 30–40 mi (48–64 km) to lower elevations in the White Pine Range. Several migration routes used by this herd face challenges to permeability, including livestock fences, impediments to the migration path from mineral extraction, competition from wild horses, and increased highway traffic.

Animal Capture and Data Collection

Sample size: 155 adult female mule deer
Relocation frequency: 1–25 hours
Project duration: 2011–2017

Data Analysis

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

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

Models derived from:

- Migration: 290 sequences from 117 individuals
- Winter: 333 sequences from 155 individuals

Corridor and Stopover Summary

Migration start and end date (median):

- Spring: March 21 to April 18
- Fall: November 17 to December 5

Days migrating (mean):

- Spring: 23 days
- Fall: 24 days

Migration length:

- Min: 8 mi (12.9 km)
- Mean: 45 mi (72.4 km)
- Max: 134 mi (215.7 km)

Migration area:

- 474,660 acres (192,088.1 ha) (low use)
- 76,754 acres (31,061.2 ha) (medium use)
- 32,793 acres (13,270.9 ha) (high use)

Stopover area: 50,998 acres (20,638.2 ha)

Winter Range Summary

Winter start and end date (median):

- December 15 to March 1

Winter length (mean): 75 days

Winter range (30 percent contour) area: 288,323 acres (116,680.2 ha)

Other Information

Project contacts:

- Cody Schroeder (cschroeder@ndow.org), Wildlife Staff Specialist, Nevada Division of Wildlife

Data analyst:

- Hall Sawyer, Wildlife Biologist, WEST, Inc.

Reports and publications:

- Blum, M.E., Stewart, K.M., and Schroeder, C., 2015, Effects of large-scale gold mining on migratory behavior of a large herbivore: Ecosphere, v. 6, no. 5, p. 1–18. [Also available at https://doi.org/10.1890/ES14-00421.1.]
- Sawyer, H., and Brittell, M., 2014, Mule deer migration and bald mountain mine-a summary of baseline data: Laramie, Wyo., USA., Western Ecosystems Technology.
- Wolff, P.L., Schroeder, C., McAdoo, C., Cox, M., Nelson, D.D., Evermann, J.F., and Ridpath, J.F., 2016, Evidence of bovine viral diarrhea virus infection in three species of sympatric wild ungulates in Nevada—Life history strategies may maintain endemic infections in wild populations: Frontiers in Microbiology, v. 7, p. 292–299. [Also available at https://doi.org/10.3389/fmicb.2016.00292.]

Photograph from Cody Schroeder.

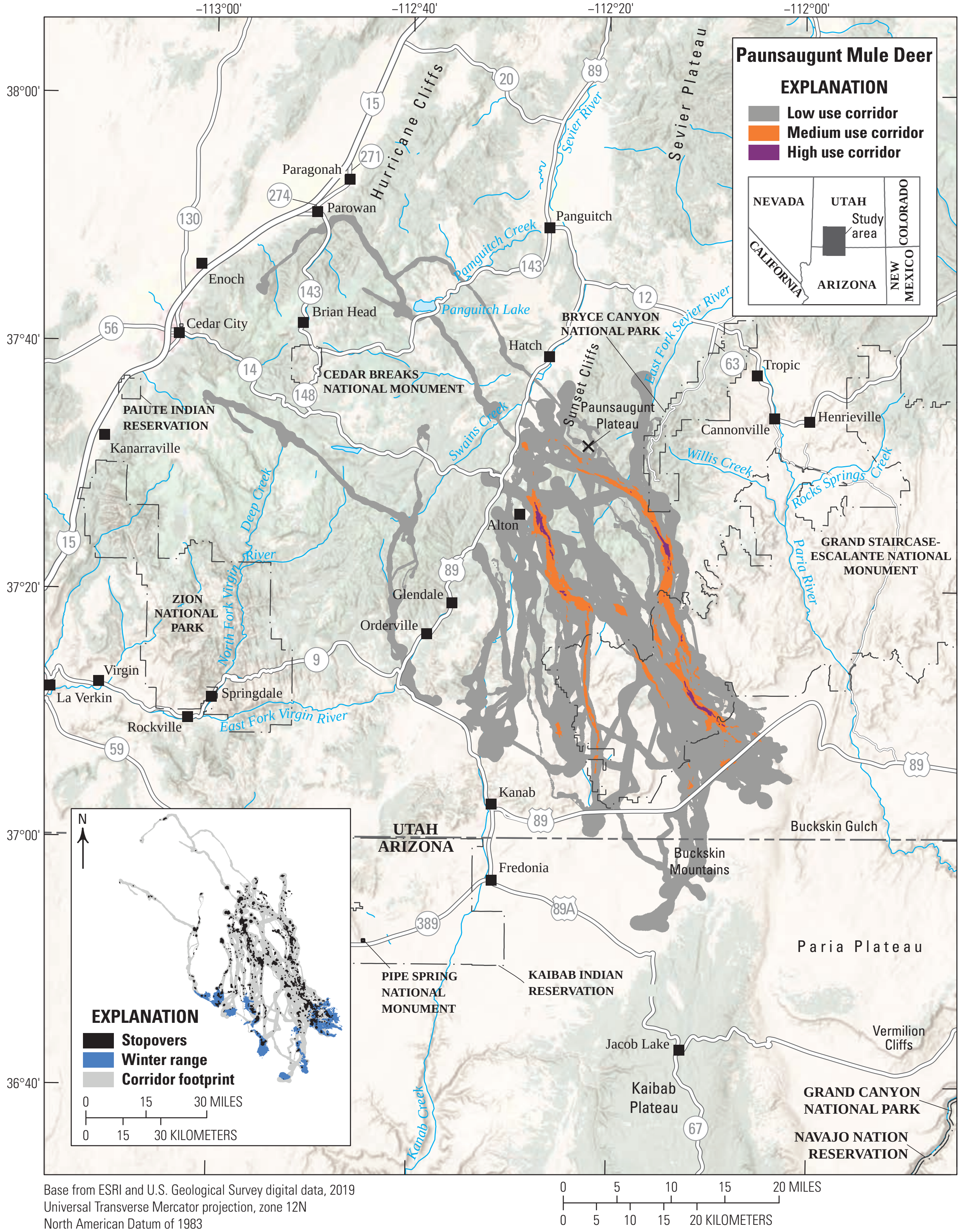


Figure 21. Migration corridors, stopovers, and winter ranges of the Paunsaugunt mule deer herd.

Utah | Mule Deer

Paunsaugunt Plateau Mule Deer Migration Corridors

The Paunsaugunt Plateau in southern Utah is home to a prolific mule deer herd numbering around 5,200 individuals in 2019. In early October, these mule deer begin their migration from the Plateau traveling south distances up to 78 mi (126 km) to winter range in the Buckskin Mountains near the Utah-Arizona border (fig. 21). Approximately 20–30 percent of the Paunsaugunt Plateau herd reside in northern Arizona during the winter, sharing winter range also used by deer from the Kaibab Plateau herd. Beginning in late April, deer reverse their migration to their summer range on the Plateau. The most significant challenge for these deer is U.S. Highway 89 which bisects this migration corridor and winter range, where 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 deer-vehicle collisions and provide connectivity for 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: 29 female/25 male adult mule deer
Relocation frequency: ~2 hours
Project duration: 2018–2019

Data Analysis

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

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

Models derived from:

- Migration: 117 sequences from 54 individuals (75 spring sequences, 42 fall sequences)
- Winter: 36 sequences from 36 individuals

Corridor and Stopover Summary

Migration start and end date (median):

- Spring: April 23 to April 30
- Fall: October 6 to October 21

Days migrating (mean):

- Spring: 11 days
- Fall: 16 days

Migration length:

- Min: 13 mi (20.9 km)
- Mean: 35 mi (56.3 km)
- Max: 79 mi (127.1 km)

Migration area:

- 399,117 acres (161,517.0 ha) (low use)
- 27,752 acres (11,230.8 ha) (medium use)
- 2,388 acres (966.4 ha) (high use)

Stopover area: 40,030 acres (16,199.6 ha)

Winter Range Summary

Winter start and end date (median):

- November 5 to April 17

Winter length (mean): 153 days

Winter range (50 percent contour) area: 58,760 acres (23,779.3 ha)

Other Information

Project contacts:

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

Data analyst:

- Lucas Olson (lolson@azgfd.gov), 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: Research Branch Technical Report No. 29: Phoenix, Ariz., Arizona Game and Fish Department, p. 44.
- Cramer, P., and Hamlin, R., 2019, U.S. 89 Kanab-Paunsaugunt wildlife crossing and existing structures research project final report: Taylorsville, Utah, Utah Department of Transportation.
- Messmer, T., and Klimack, P., 1999, Summer habitat use and migration movements of the Paunsaugunt Plateau mule deer herd final report: Salt Lake City, Utah, Utah Division of Wildlife Resources.

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

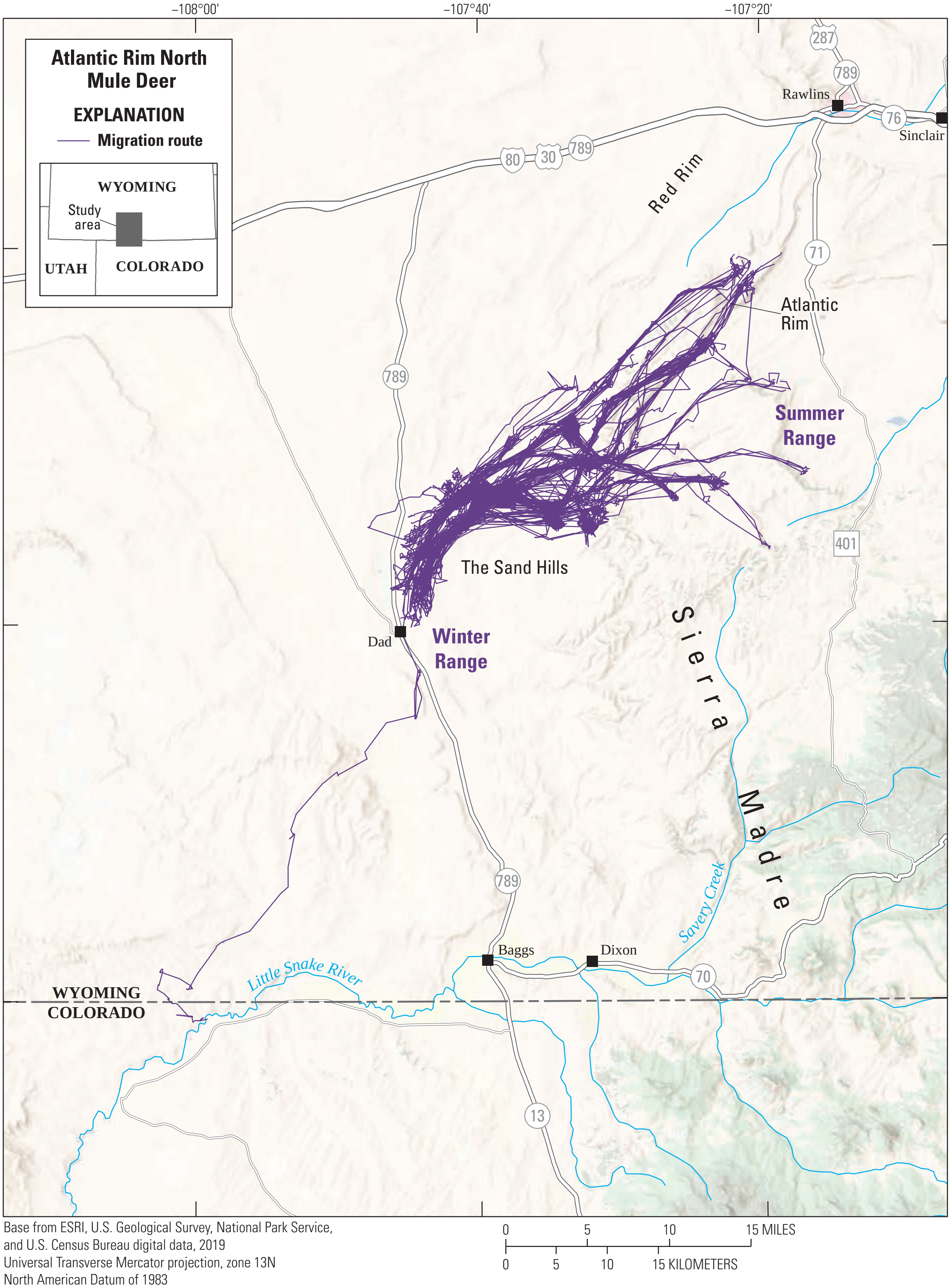


Figure 22. Migration routes of the Atlantic Rim North mule deer population.

Wyoming | Mule Deer

Baggs Herd: Atlantic Rim North Mule Deer Migration Routes

Mule deer in the Atlantic Rim North population are part of the Baggs herd unit that is managed for approximately 19,000 animals. These mule deer winter in the pinyon-juniper and sagebrush badlands near Dad, Wyoming and migrate north and east 10–35 mi (16–56 km) to various summer ranges (fig. 22). Many of these deer must navigate coal-bed methane development that is situated along the migration route between their seasonal ranges. In addition to gas development, portions of their summer range overlap with areas of wind-energy development; roadway mortality remains an issue on Highway 789.

Animal Capture and Data Collection

Sample size: 55 adult female mule deer
Relocation frequency: 2–3 hours
Project duration: 2005–2019

Data Analysis

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others 2011)
Models derived from:

- Migration: 147 sequences from 47 individuals
- Winter: 115 sequences from 55 individuals

Route Summary

Migration start and end date (median):

- Spring: April 24 to May 1
- Fall: October 27 to December 2

Days migrating (mean):

- Spring: 12 days
- Fall: 29 days

Migration route length:

- Min: 9 mi (14.5 km)
- Mean: 23 mi (37.0 km)
- Max: 57 mi (91.7 km)

Winter Use Summary

Winter use start and end date (median):

- January 1 to March 15

Days of winter use (mean): 74 days

Other Information

Project contacts:

- Hall Sawyer (hsawyer@west-inc.com), Wildlife Biologist, WEST Inc.
- Philip Damm (philip.damm@wyo.gov), Wildlife Biologist, Wyoming Game and Fish Department
- Tony Mong (tony.mong@wyo.gov), Wildlife Biologist, Wyoming Game and Fish Department

Data analyst:

- Hall Sawyer, Wildlife Biologist, WEST Inc.

Reports and publications:

- Sawyer, H., Kauffman, M.J., Nielson, R.M., and Horne, J.S., 2009b, Identifying and prioritizing ungulate migration routes for landscape-level conservation: Ecological Applications, v. 19, no. 8, p. 2016–2025. [Also available at https://doi.org/10.1890/08-2034.1.]
- Sawyer, H., and Kauffman, M.J., 2011, Stopover ecology of a migratory ungulate: Journal of Animal Ecology, v. 80, no. 5, p. 1078–1087. [Also available at https://doi.org/10.1111/j.1365-2656.2011.01845.x.]
- Sawyer, H., Kauffman, M.J., Middleton, A.D., Morrison, T.A., Nielson, R.M., and Wyckoff, T.B., 2013, A framework for understanding semi-permeable barrier effects on migratory ungulates: Journal of Applied Ecology, v. 50, no. 1, p. 68–78. [Also available at https://doi.org/10.1111/1365-2664.12013.]

Photograph from Tony Mong, Wyoming Game and Fish Department.

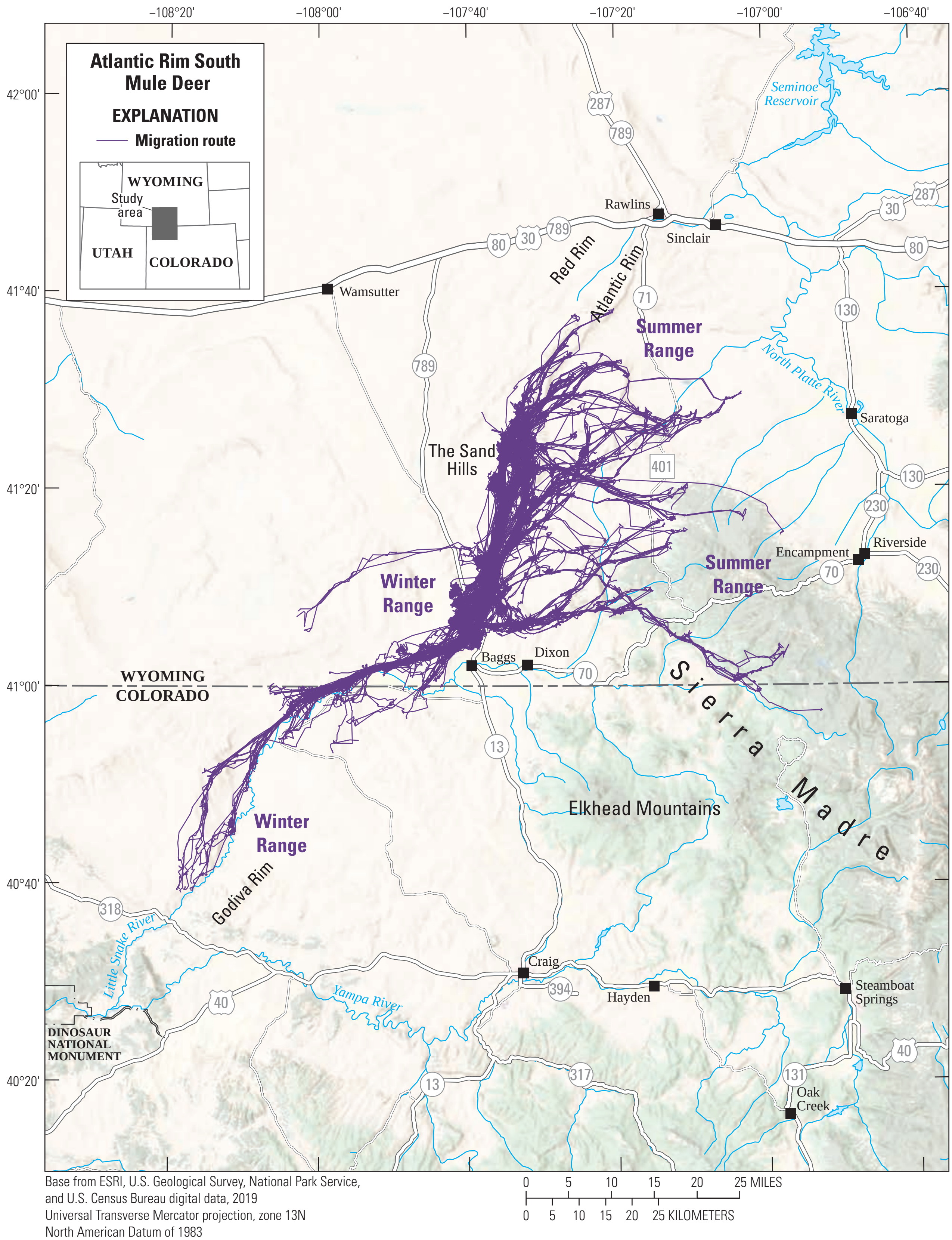


Figure 23. Migration routes of the Atlantic Rim South mule deer population.

Wyoming | Mule Deer

Baggs Herd: Atlantic Rim South Mule Deer Migration Routes

Mule deer in the Atlantic Rim South population are part of the Baggs herd unit that is managed for approximately 19,000 animals. These mule deer winter in the sagebrush canyons and basins north and west of Baggs, Wyoming and migrate north and east 20–50 mi (32–80 km) to various summer ranges (fig. 23). Many of these deer must navigate coal-bed methane developments situated along the migration route between their seasonal ranges. In addition to navigating gas developments, many of these deer cross Highway 789 during winter and migration. The Wyoming Department of Transportation (WYDOT) recently installed two underpasses and several mi of game-proof fencing to facilitate highway crossings across Highway 789 and help minimize wildlife-vehicle collisions and maintain corridor connectivity.

Animal Capture and Data Collection

Sample size: 104 adult female mule deer
Relocation frequency: 2–3 hours
Project duration: 2005–2019

Data Analysis

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others 2011)
Models derived from:

- Migration: 277 sequences from 89 individuals
- Winter: 215 sequences from 104 individuals

Route Summary

Migration start and end date (median):

- Spring: April 9 to May 1
- Fall: October 23 to December 9

Days migrating (mean):

- Spring: 26 days
- Fall: 38 days

Migration route length:

- Min: 6 mi (9.7 km)
- Mean: 41 mi (66.0 km)
- Max: 89 mi (143.2 km)

Winter Use Summary

Winter use start and end date (median):

- January 1 to March 15

Days of winter use (mean): 74 days

Other Information

Project contacts:

- Hall Sawyer (hsawyer@west-inc.com), Wildlife Biologist, WEST Inc.
- Tony Mong (tony.mong@wyo.gov), Wildlife Biologist, Wyoming Game and Fish Department

Data analyst:

- Hall Sawyer, Wildlife Biologist, WEST Inc.

Reports and publications:

- Sawyer, H., Kauffman, M.J., Nielson, R.M., and Horne, J.S., 2009b, Identifying and prioritizing ungulate migration routes for landscape-level conservation: Ecological Applications, v. 19, no. 8, p. 2016–2025. [Also available at https://doi.org/10.1890/08-2034.1.]
- Sawyer, H., and Kauffman, M.J., 2011, Stopover ecology of a migratory ungulate: Journal of Animal Ecology, v. 80, no. 5, p. 1078–1087. [Also available at https://doi.org/10.1111/j.1365-2656.2011.01845.x.]
- Sawyer, H., Kauffman, M.J., Middleton, A.D., Morrison, T.A., Nielson, R.M., and Wyckoff, T.B., 2013, A framework for understanding semi-permeable barrier effects on migratory ungulates: Journal of Applied Ecology, v. 50, no. 1, p. 68–78. [Also available at https://doi.org/10.1111/1365-2664.12013.]

Photograph from Tony Mong, Wyoming Game and Fish Department.

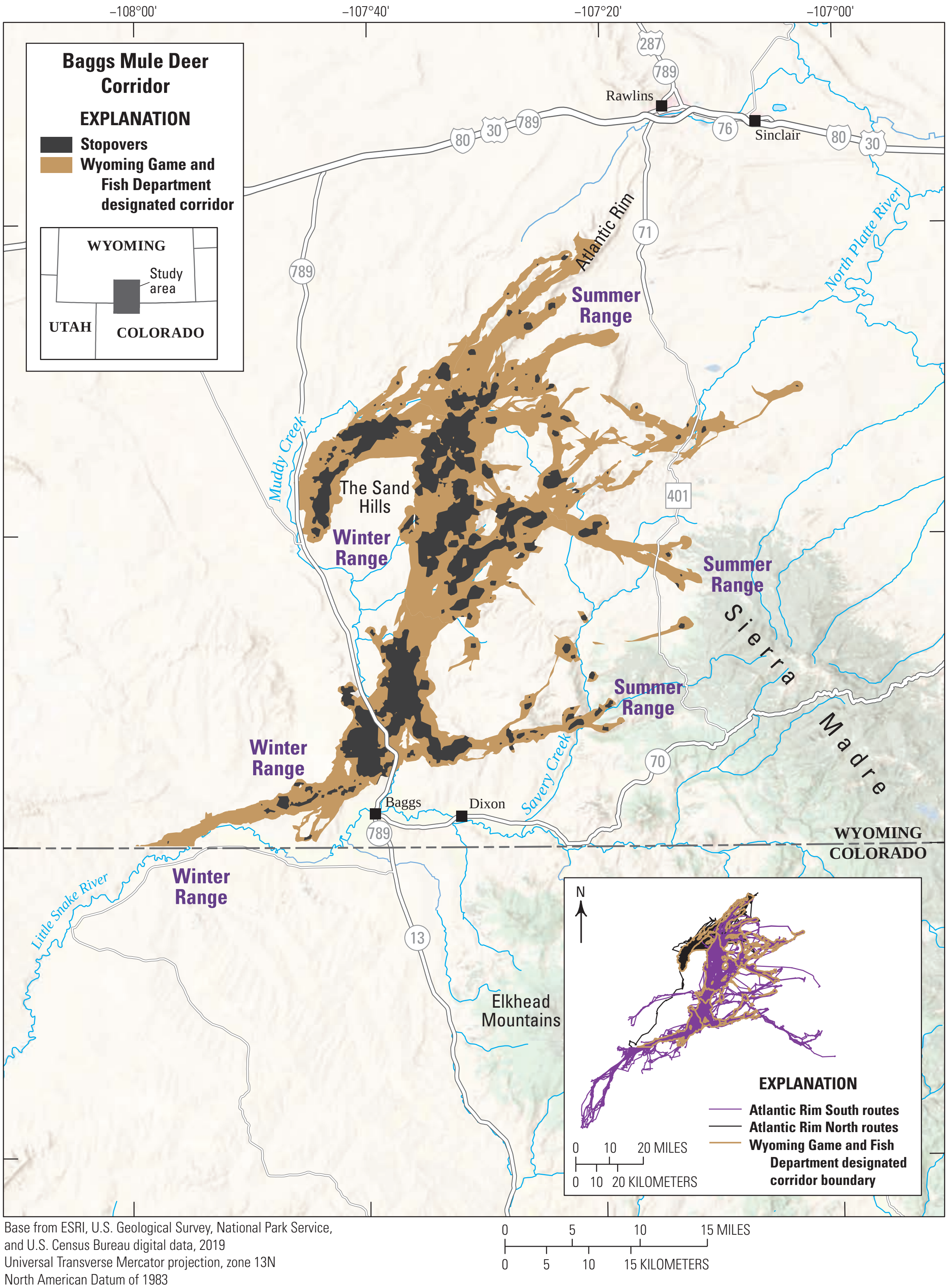


Figure 24. WGFD Designated Corridor, stopovers and routes of the Baggs mule deer herd.

Wyoming | Mule Deer

Baggs Herd: WGFD Designated Corridor

The Baggs Mule Deer Corridor was officially designated by the Wyoming Game and Fish Department (WGFD) in 2018 (fig. 24). The Baggs Herd is managed for approximately 19,000 animals, and the corridor is based on two wintering deer populations: a northern and southern segment. Animals in the north segment occupy a relatively small winter range along a pinyon-juniper ridge that runs along the east side of Highway 789. From there, deer migrate north and west to summer ranges on Atlantic Rim, the Sand Hills, and the head of Savery Creek. The southern segment occupies a larger sagebrush winter range on both sides of Highway 789, some of which extends into Colorado. These animals migrate north and west to summer ranges in and around the Sierra Madre.

Corridor and Stopover Summary

Migration corridor area: 252,223 acres (103,071.0 ha) (WGFD designation)

Stopover area: 69,209 acres (28,008 hectares)

Other Information

Agency contacts:

- Mark Zornes (mark.zornes@wyo.gov), Wildlife Management Coordinator, Green River Region, Wyoming Game and Fish Department
- Philip Damm (philip.damm@wyo.gov), Wildlife Biologist, Wyoming Game and Fish Department

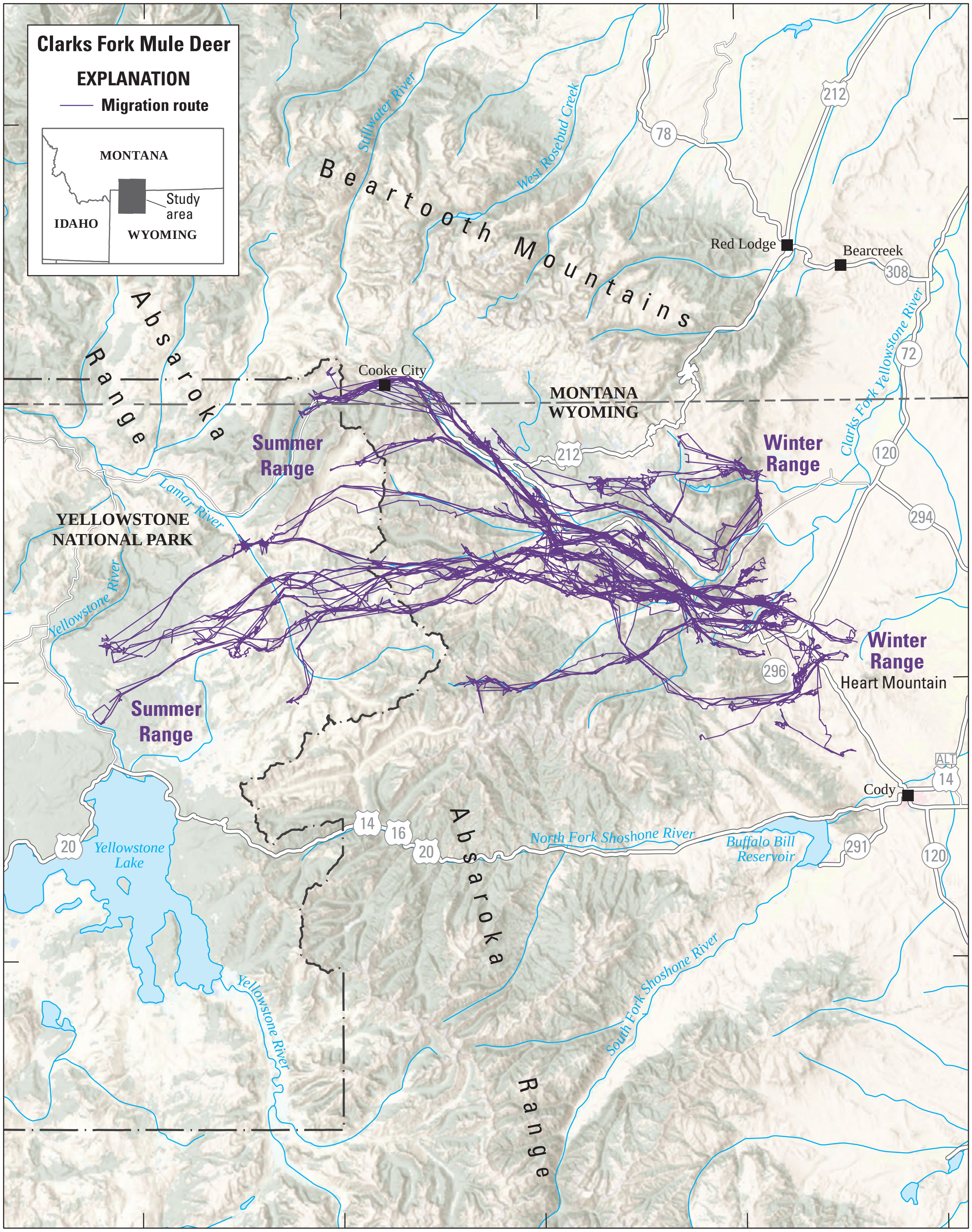
Data analyst:

- Hall Sawyer, Wildlife Biologist, WEST, Inc

Reports and publications:

- Sawyer, H., and Telander, A., 2019, Atlantic Rim mule deer study—phase 3 final report: Laramie, WY, Western Ecosystems Technology.
- Sawyer, H., Kauffman, M.J., Nielson, R.M., and Horne, J.S., 2009b, Identifying and prioritizing ungulate migration routes for landscape-level conservation: Ecological Applications, v. 19, no. 8, p. 2016–2025. [Also available at https://doi.org/10.1890/08-2034.1.]
- Sawyer, H., Kauffman, M.J., Middleton, A.D., Morrison, T.A., Nielson, R.M., and Wyckoff, T.B., 2013, A framework for understanding semi-permeable barrier effects on migratory ungulates: Journal of Applied Ecology, v. 50, no. 1, p. 68–78. [Also available at https://doi.org/10.1111/1365-2664.12013.]

Photograph from Patrick Rogers.



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 5 10 15 20 MILES
0 5 10 15 20 KILOMETERS

Figure 25. Migration routes of the Clarks Fork mule deer herd.

Wyoming | Mule Deer

Clarks Fork Mule Deer Migration Routes

Mule deer within the Clarks Fork herd make a number of significant westward long-distance migrations (fig. 25). These migrations originate north of Cody, near Heart Mountain and along the foothills of Absaroka Front. There, deer winter in the lower-elevation sagebrush valleys. In spring, an estimated 2,700 deer head west into the high-elevation mountain valleys of the Absaroka Range and Yellowstone National Park. This herd summers along the Lamar River, Cache Creek, and the Clarks Fork of the Yellowstone. The longest migration is 68 mi (109 km) and ends just north of Yellowstone Lake along the Yellowstone River. These challenging journeys, an average of 38 mi (61 km) long, cross rugged terrain and steep mountain passes such as those at the head of Sunlight Creek at 11,400 ft (3,474 m) in elevation. Deer must also navigate human-created obstacles such as fences and the Beartooth Highway (U.S. Highway 212).

Animal Capture and Data Collection

Sample size: 31 adult female mule deer
Relocation frequency: ~2 hours
Project duration: 2016–2019

Data Analysis

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

Models derived from:

- Migration: 79 sequences from 29 individuals (43 spring sequences, 36 fall sequences)
- Winter: 41 sequences from 28 individuals

Route Summary

Migration start and end date (median):

- Spring: May 11 to May 30
- Fall: October 6 to October 25

Days migrating (mean):

- Spring: 20 days
- Fall: 20 days

Migration route length:

- Min: 6.2 mi (10.0 km)
- Mean: 37.5 mi (60.4 km)
- Max: 68.1 mi (109.6 km)

Winter Use Summary

Winter use start and end date (median):

- December 1 day to March 25

Days of winter use (mean): 102 days

Other Information

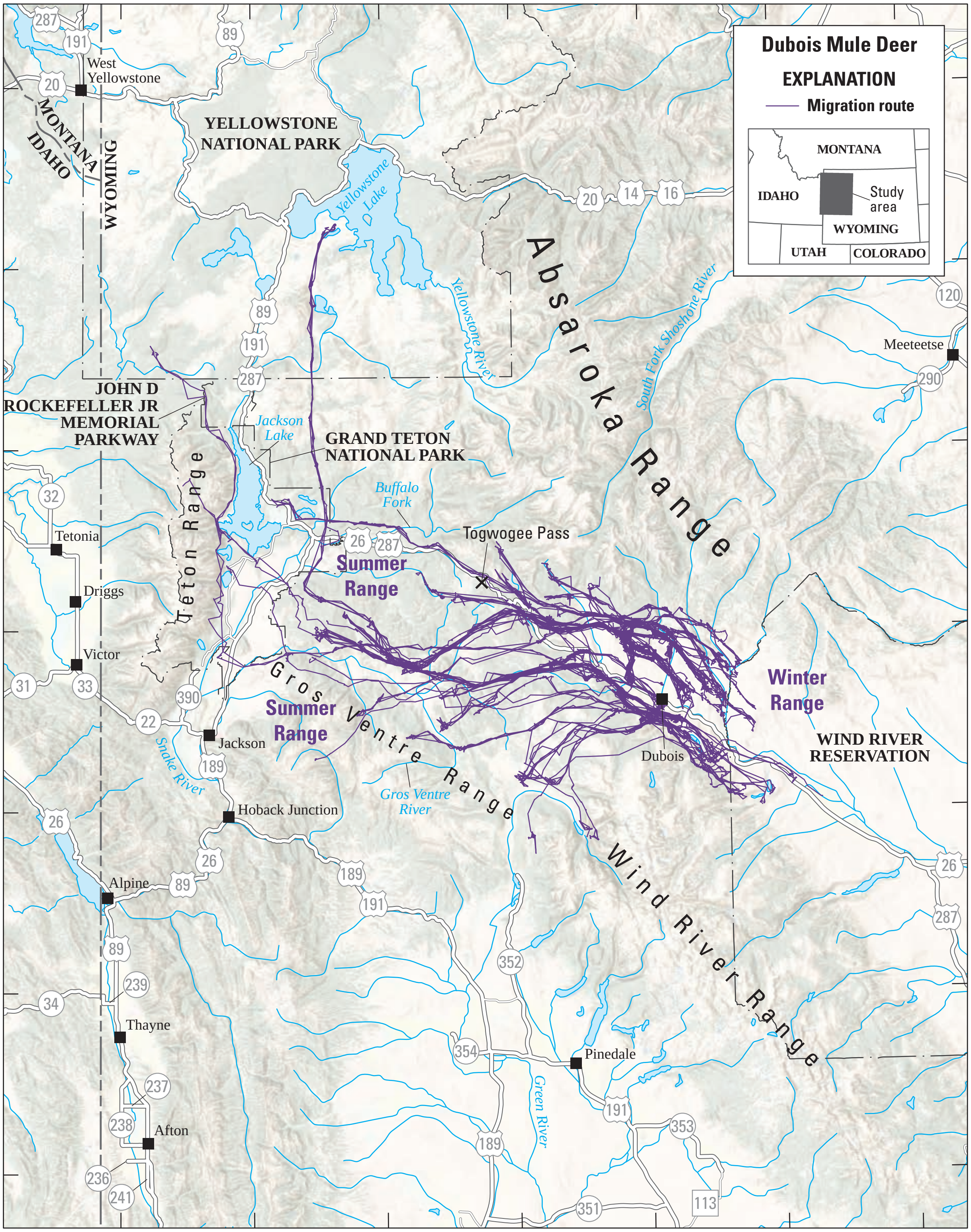
Project contacts:

- Matthew Kauffman (mkauffm1@uwyo.edu), U.S. Geological Survey, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming
- Corey Class (corey.class@wyo.gov), Wildlife Management Coordinator, Wyoming Game and Fish Department
- Tony Mong (tony.mong@wyo.gov), Wildlife Biologist, Wyoming Game and Fish Department

Data analyst:

- Julien Fattebert, Post Doctoral Researcher, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming

Photograph from Gregory Nickerson.



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

Figure 26. Migration routes of the Dubois mule deer population.

Wyoming | Mule Deer

Dubois Mule Deer Migration Routes

Mule deer within the Dubois herd make several long-distance migrations into the heart of the Greater Yellowstone Ecosystem (fig. 26). These migrations originate from winter range in the warm, protected sagebrush valley surrounding Dubois, Wyoming, and extend to the southeast on the Wind River Reservation. Each spring, an estimated 6,000–7,000 deer leave this valley and the Reservation and migrate northwest. These journeys, averaging 44 mi one way, begin as deer ascend Togwotee Pass (9,658 ft [m 2,944] in elevation). From there, they cross challenging natural terrain with high mountain passes and disperse into the north Wind River Range, Gros Ventre Range, Absaroka Range, Grand Teton National Park, and deep into Yellowstone National Park. The longest migration is 105 mi (169 km) and ends in Yellowstone National Park. This deer herd encounters a number of challenges related to human activity such as housing developments on the outskirts of Dubois, roads, and fences. Deer-vehicle collisions along U.S. Highway 287/U.S. Route 26 are a particular concern and a priority for mitigation measures that reduce deer mortality and improve motorist safety.

Animal Capture and Data Collection

Sample size: 49 adult female mule deer
Relocation frequency: 2–24 hours
Project duration: 2014–2019

Data Analysis

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

Models derived from:

- Migration: 108 sequences from 41 individuals (56 spring sequences, 52 fall sequences)
- Winter: 94 sequences from 46 individuals

Route Summary

Migration start and end date (median):

- Spring: May 14 to June 5
- Fall: October 14 to November 5

Days migrating (mean):

- Spring: 22 days
- Fall: 26 days

Migration route length:

- Min: 12 mi (19.3 km)
- Mean: 44 mi (70.8 km)
- Max: 105 mi (169.0 km)

Winter Use Summary

Winter use start and end date (median):

- December 28 to April 24

Days of winter use (mean): 74 days

Other Information

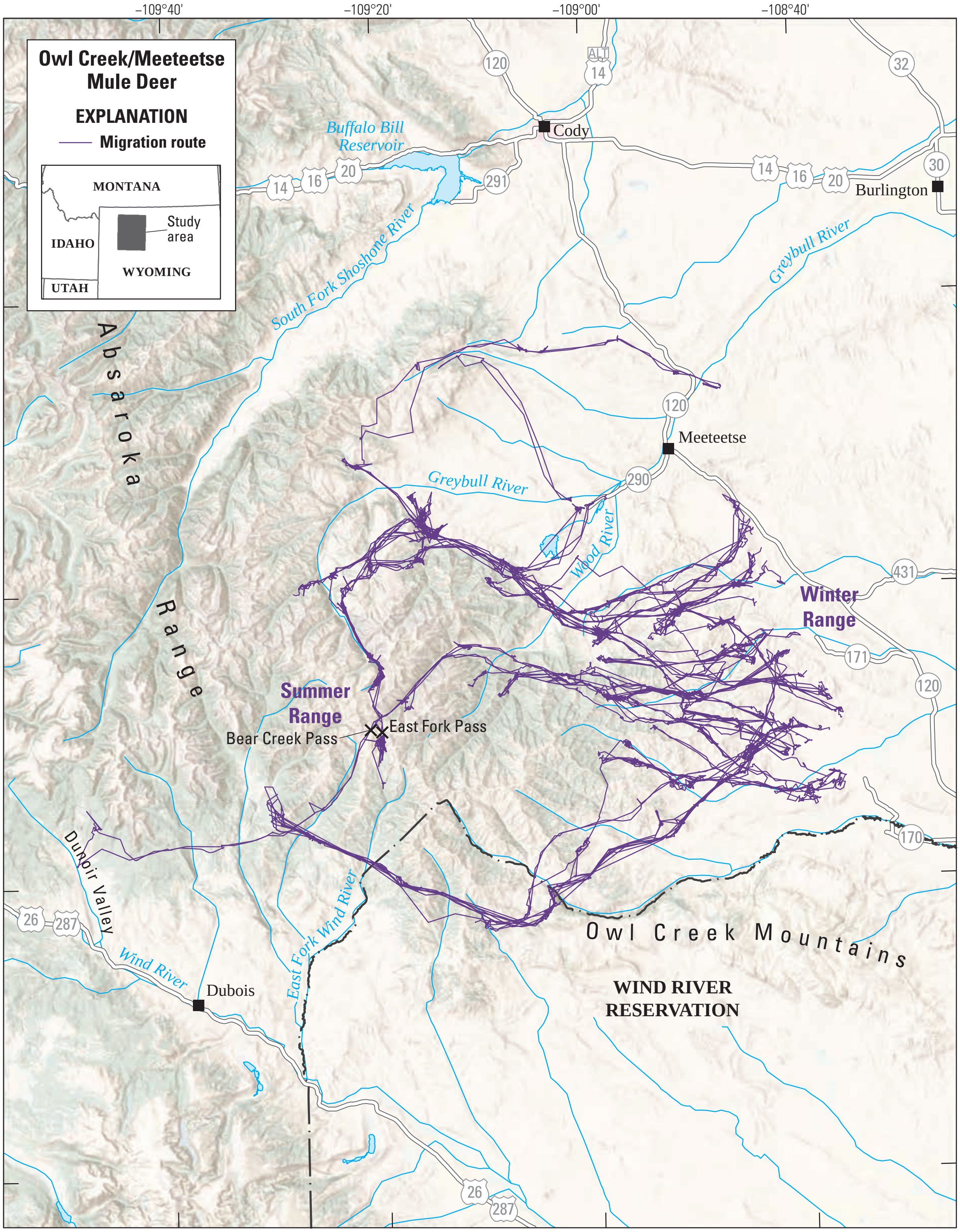
Project contacts:

- Matt Kauffman (mkauffm1@uwyo.edu), U.S. Geological Survey, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming
- Greg Anderson (gregory.anderson@wyo.gov), Wildlife Biologist, Wyoming Game and Fish Department
- Daryl Lutz (daryl.lutz@wyo.gov), Wildlife Management Coordinator, Wyoming Game and Fish Department
- Pat Hnilicka (pat_hnilicka@fws.gov), Wildlife Biologist, U.S. Fish and Wildlife Service
- Sarah Dewey (sarah_dewey@nps.gov), Wildlife Biologist, National Park Service

Data analyst:

- Holly Copeland, Sr. Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming, USA.

Photograph from Dubois.



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

Figure 27. Migration routes of the Owl Creek/Meeteetse mule deer herd population.

Wyoming | Mule Deer

Owl Creek/Meeteetse Mule Deer Migration Routes

Mule deer within the Owl Creek/Meeteetse herd make a number of medium- to long-distance migrations (fig. 27). These migrations originate on the sagebrush grasslands just southwest and west of Meeteetse, Wyoming, where this population winters. In spring, an estimated 4,100 deer leave these foothills and travel into the rugged Absaroka Range. These journeys across challenging natural terrain cover an average of 27 mi (43 km). Migration routes include navigating fast-moving rivers, such as the Greybull River, and crossing over high mountains passes like Bear Creek and East Fork Pass, the highest of which is 12,230 ft (3,728 m) in elevation. The longest migration is 70 mi (113 km) to the Dunoir Valley northwest of Dubois. Although the private lands that compose winter range and low-elevation route segments are at risk of residential development, deer encounter few human-created obstacles in a remote wilderness environment once they cross onto the National Forest.

Animal Capture and Data Collection

Sample size: 37 adult female mule deer
Relocation frequency: ~2 hours
Project duration: 2016–2019

Data Analysis

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

Models derived from:

- Migration: 86 sequences from 32 individuals (45 spring sequences, 41 fall sequences)
- Winter: 46 sequences from 29 individuals

Route Summary

Migration start and end date (median):

- Spring: May 4 to May 25
- Fall: October 3 to October 13

Days migrating (mean):

- Spring: 20.2 days
- Fall: 12.3 days

Migration route length:

- Min: 10 mi (16.1 km)
- Mean: 27 mi (43.5 km)
- Max: 70 mi (112.7 km)

Winter Use Summary

Winter use start and end date (median):

- November 20 to April 06

Days of winter use (mean): 119 days

Other Information

Project contacts:

- Matthew Kauffman (mkauffm1@uwyo.edu), U.S. Geological Survey, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming
- Corey Class (corey.class@wyo.gov), Wildlife Management Coordinator, Wyoming Game and Fish Department
- Bart Kroger (bart.kroger@wyo.gov), Wildlife Biologist, Wyoming Game and Fish Department

Data analyst:

- Emily Gelzer, University of Wyoming, Department of Zoology and Physiology

Photograph from Gregory Nickerson.

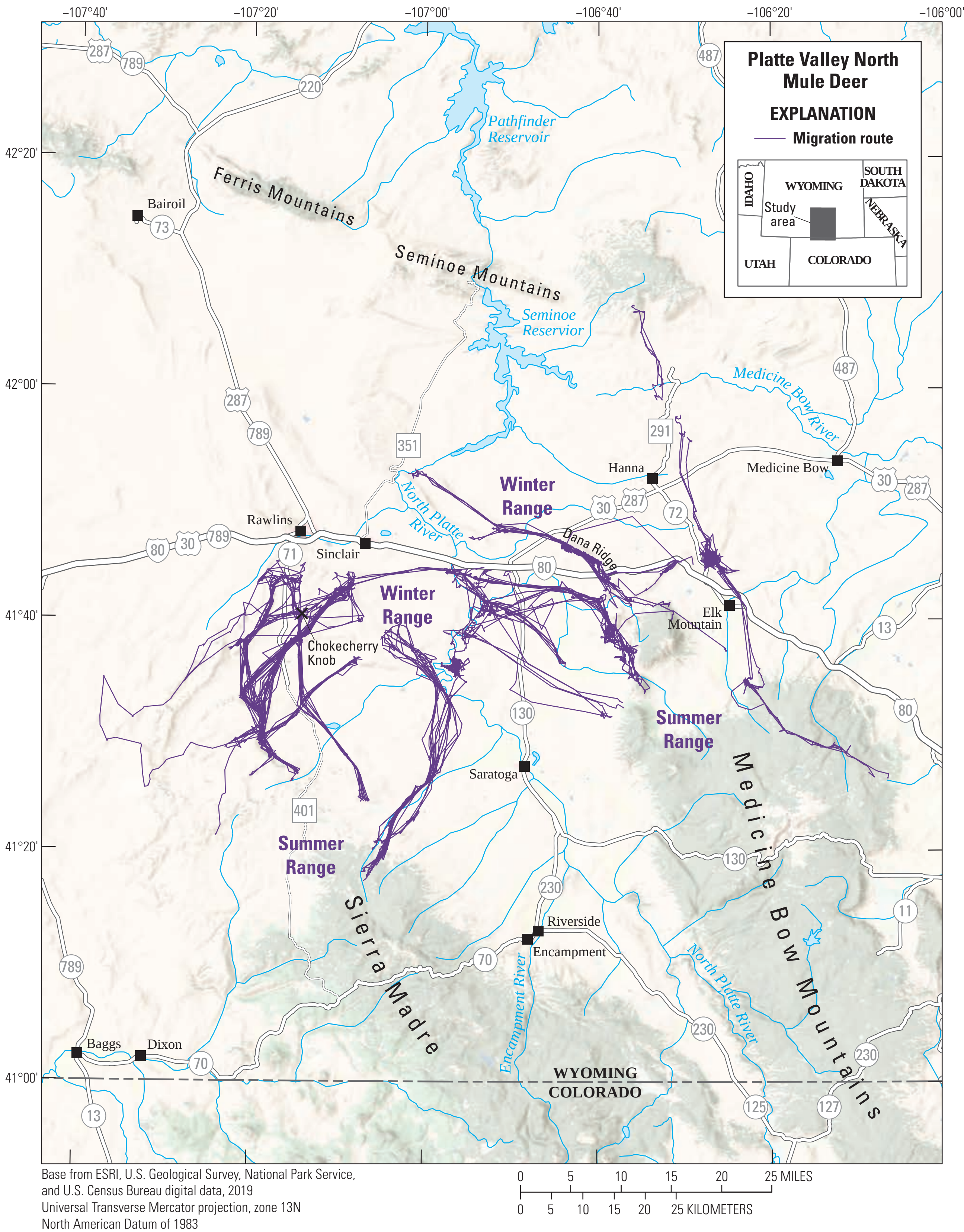


Figure 28. Migration routes of the Platte Valley North mule deer population.

Wyoming | Mule Deer

Platte Valley Herd: Platte Valley North Mule Deer Migration Routes

Mule deer in the Platte Valley North population are part of the larger Platte Valley herd unit with an estimated population of 11,000 animals (fig. 28). These mule deer winter in the sagebrush canyons and basins near the Platte River north of Saratoga, Wyoming. Other segments of this population winter in the Chokecherry Knob area, south of Sinclair, and the Dana Ridge area just north of I-80. The migratory patterns of these deer are diverse and vary with each winter range. Deer in this part of the Platte Valley have a noticeably higher proportion of resident animals compared to the Platte Valley South population. For example, half of the mule deer near I-80 are residents. Improving the connectivity of deer migration across I-80 has become a management priority in order to reduce wildlife-vehicle collisions and to provide deer with access to more habitat. Wind-energy development is a major concern for the northwest part of the Platte Valley, where 1,000 turbines are slated for construction beginning in 2022. The potential impacts of wind development on mule deer are being investigated.

Animal Capture and Data Collection

Sample size: 104 adult female mule deer
Relocation frequency: ~2 hours
Project duration: 2011–2018

Data Analysis

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

Models derived from:

- Migration: 131 sequences from 32 individuals
- Winter: 113 sequences from 40 individuals

Route Summary

Migration start and end date (median):

- Spring: May 7 to May 15
- Fall: October 20 to October 27

Days migrating (mean):

- Spring: 8 days
- Fall: 9 days

Migration route length:

- Min: 9 mi (14.5 km)
- Mean: 23 mi (37.0 km)
- Max: 60 mi (96.6 km)

Winter Use Summary

Winter use start and end date (median):

- December 1 to March 15

Days of winter use (mean): 103 days

Other Information

Project contacts:

- Hall Sawyer (hsawyer@west-inc.com), Wildlife Biologist, WEST Inc.
- Embere Hall (embere.hall@wyo.gov), Wildlife Management Coordinator, Wyoming Game and Fish Department
- Teal Cufaude (teal.cufaude@wyo.gov), Wildlife Biologist, Wyoming Game and Fish Department

Data analyst:

- Hall Sawyer, Wildlife Biologist, WEST Inc.

Reports and publications:

- Kauffman, M.J., Sawyer, H., Schultz, W., and Hayes, M., 2015, Seasonal ranges, migration, habitat use of the Platte Valley mule deer herd: Laramie, Wyo., Wyoming Cooperative Fish and Wildlife Research Unit.

Photograph from Gregory Nickerson.

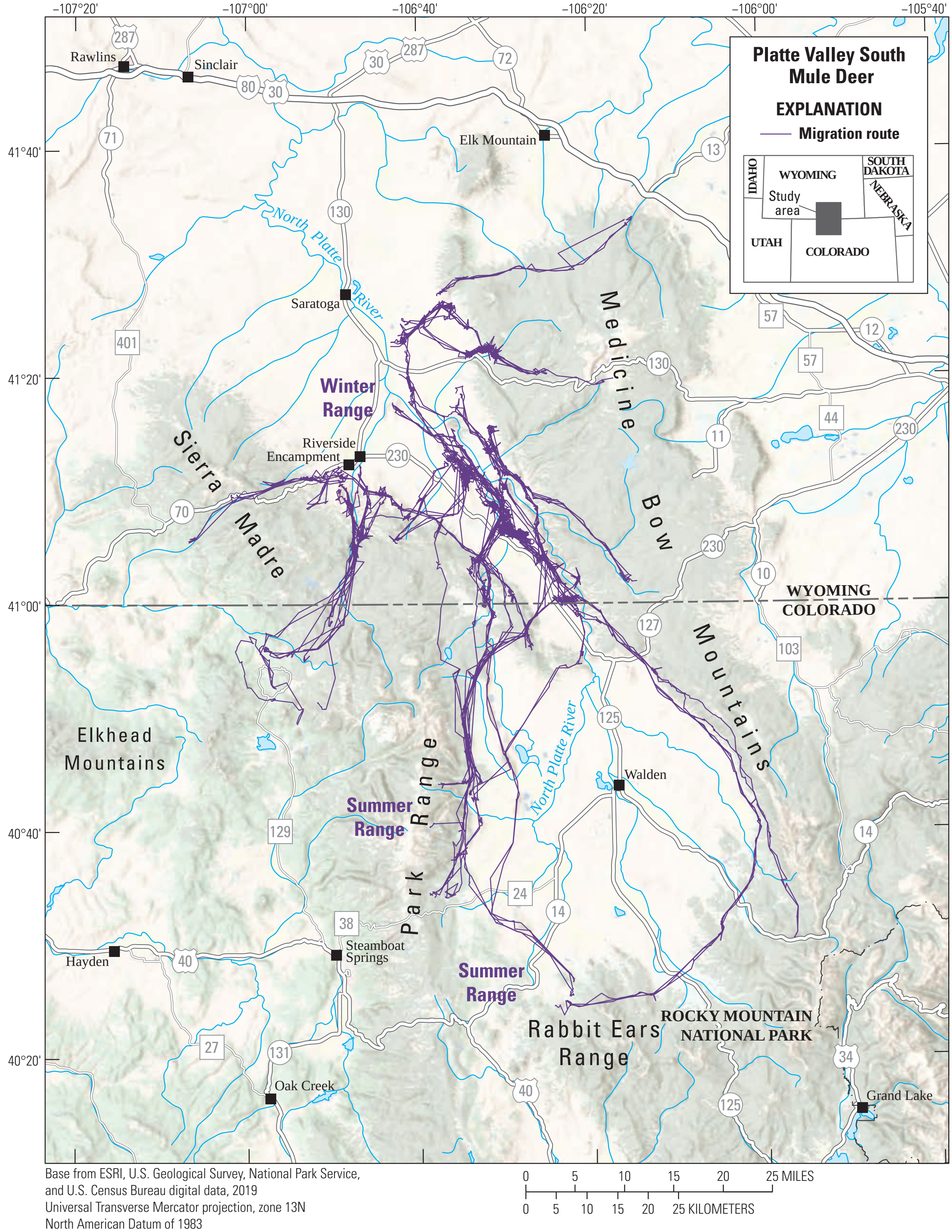


Figure 29. Migration routes of the Platte Valley South mule deer population.

Wyoming | Mule Deer

Platte Valley Herd: Platte Valley South Mule Deer Migration Routes

Mule deer in the Platte Valley South population are part of the larger Platte Valley herd unit with an estimated population of 11,000 animals. These mule deer winter in the sagebrush canyons and basins near the Platte and Encampment Rivers, south of Saratoga, Wyoming (fig. 29). Most of these deer migrate southerly 20–70 mi (32–113 km) to portions of the Sierra Madre, Medicine Bow Mountains, and Park Range in northern Colorado and southern Wyoming. Some of these deer move as far south as Rabbit Ears Range and must negotiate numerous fences, highways, and residential development to complete their migrations.

Animal Capture and Data Collection

Sample size: 35 adult female mule deer
Relocation frequency: ~2 hours
Project duration: 2011–2013

Data Analysis

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

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

Models derived from:

- Migration: 81 sequences from 28 individuals
- Winter: 80 sequences from 35 individuals

Route Summary

Migration start and end date (median):

- Spring: April 27 to May 21
- Fall: October 16 to November 17

Days migrating (mean):

- Spring: 24 days
- Fall: 21 days

Migration route length:

- Min: 4 mi (6.4 km)
- Mean: 30 mi (48.3 km)
- Max: 83 mi (133.6 km)

Winter Use Summary

Winter use start and end date (median):

- December 1 to March 15

Days of winter use (mean): 103 days

Other Information

Project contacts:

- Hall Sawyer (hsawyer@west-inc.com), Wildlife Biologist, WEST Inc.
- Matt Kauffman (mkauffm1@uwyo.edu), U.S. Geological Survey, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming
- Embere Hall (embere.hall@wyo.gov), Wildlife Management Coordinator, Wyoming Game and Fish Department
- Teal Cufaude (teal.cufaude@wyo.gov), Wildlife Biologist, Wyoming Game and Fish Department

Data analyst:

- Hall Sawyer, Wildlife Biologist, WEST Inc.

Reports and publications:

- Kauffman, M.J., Sawyer, H., Schultz, W., and Hayes, M., 2015, Seasonal ranges, migration, habitat use of the Platte Valley mule deer herd: Laramie, Wyo., Wyoming Cooperative Fish and Wildlife Research Unit.

Photograph from Gregory Nickerson.

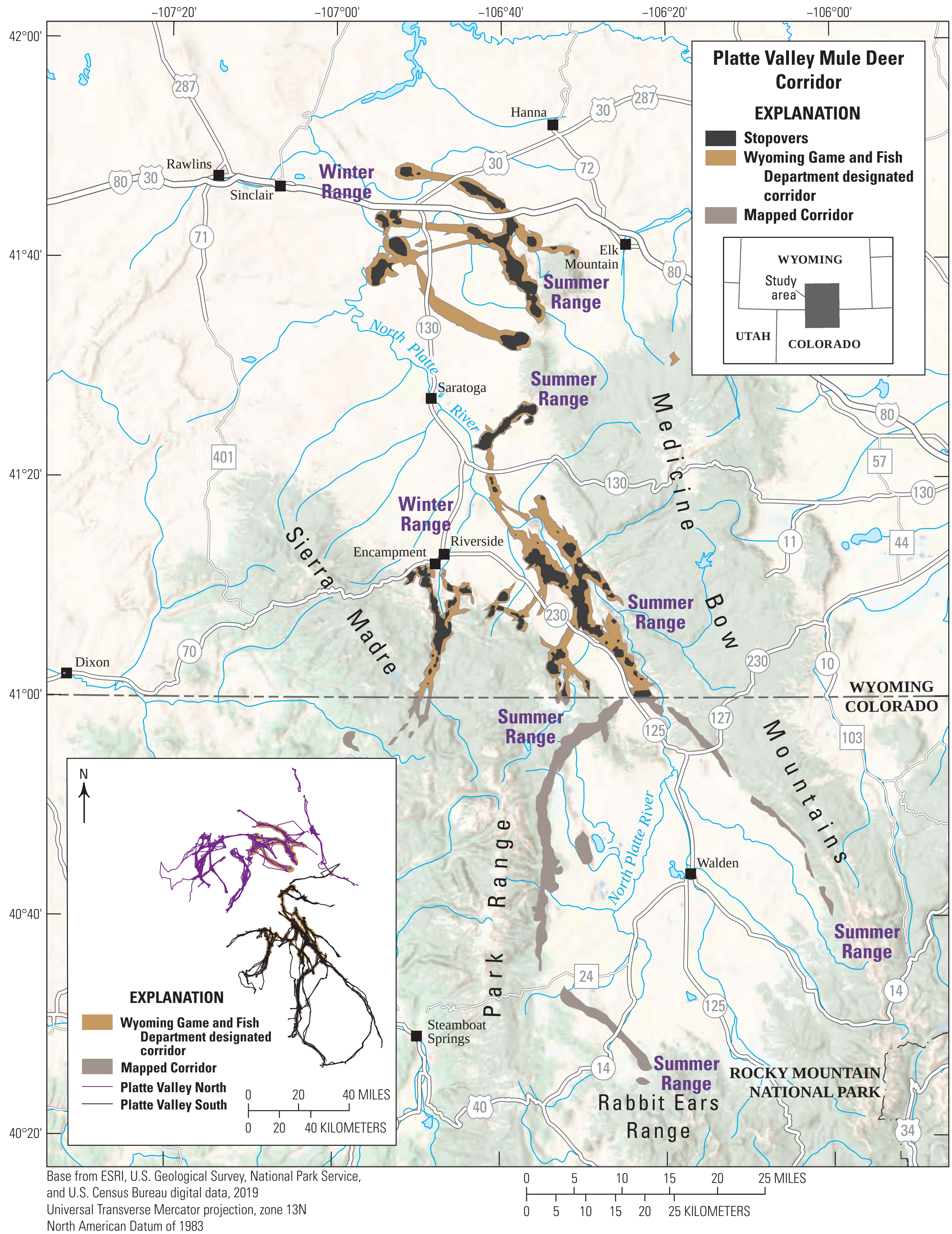


Figure 30. WGFD Designated Corridor, stopovers and routes of the Platte Valley mule deer herd.

Wyoming | Mule Deer

Platte Valley Herd: WGFD Designated Corridor

The Platte Valley Herd Corridor was designated by the Wyoming Game and Fish Department in 2018 (fig. 30). The Platte Valley herd contains approximately 11,000 mule deer. The corridor is based on two wintering populations, including a south segment from Saratoga, Wyoming, to the Colorado State line, and a north segment from Saratoga to the Dana Ridge area north of I-80. Winter ranges in the Platte Valley are more dispersed than winter ranges in other parts of the state, so deer migrate in many different directions. Many deer in the southern segment follow the Platte River south to summer ranges in Colorado. Most deer migrations in the north radiate south and east from winter ranges along I-80. The WGFD collared 45 additional mule deer in 2020 to help refine corridor delineations for this herd unit.

Corridor and Stopover Summary

Migration corridor area: 126,522 acres (51,201 ha) (WGFD designation)

Stopover area: 51,328 acres (20,772 ha)

Other Information

Agency contacts:

- Embere Hall (embere.hall@wyo.gov), Wildlife Management Coordinator, Laramie Region, Wyoming Game and Fish Department
- Teal Cufaude (teal.cufaude@wyo.gov), Wildlife Biologist, Wyoming Game and Fish Department

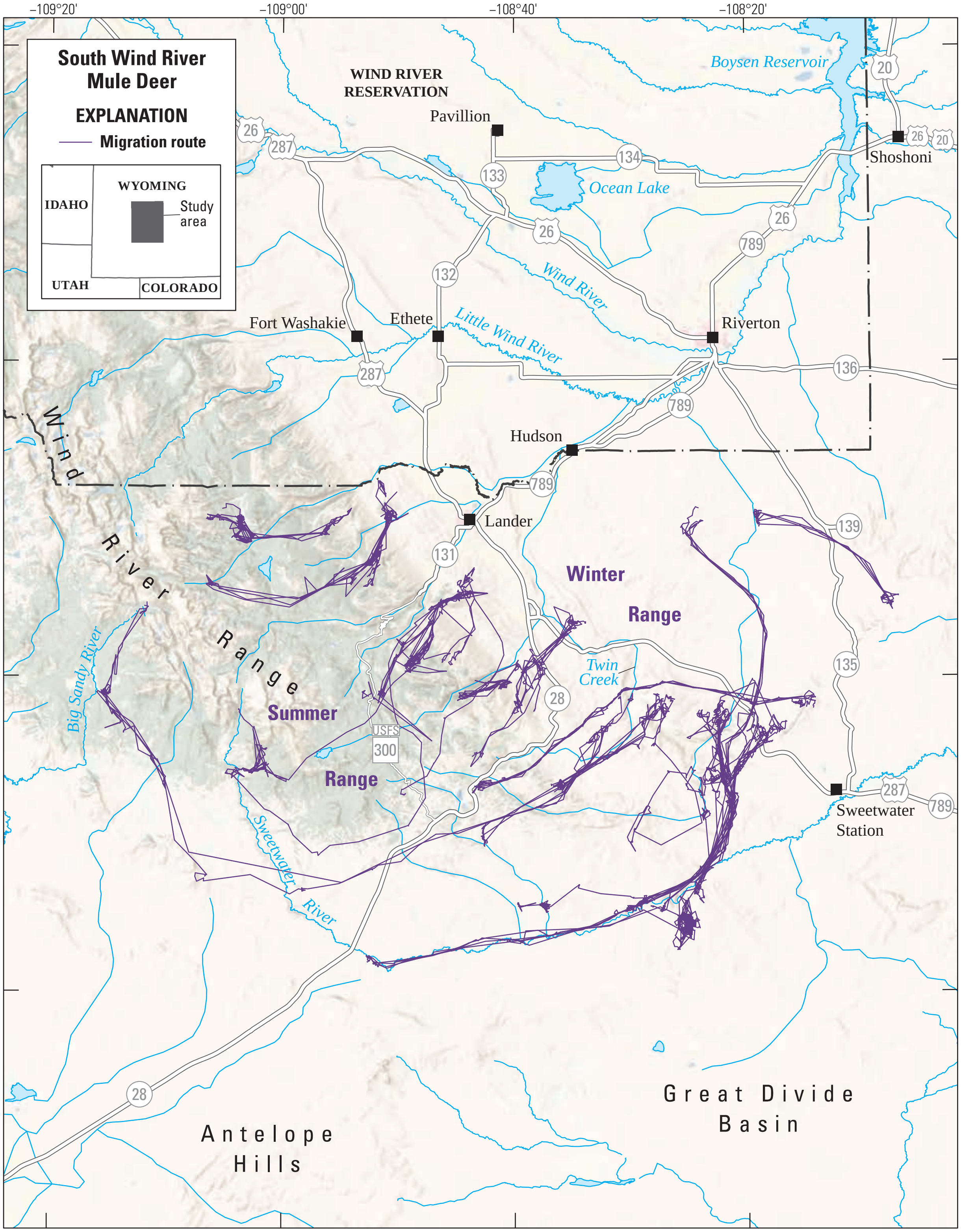
Data analyst:

- Hall Sawyer, Wildlife Biologist, WEST, Inc.

Reports and publications:

- Kauffman, M.J., Sawyer, H., Schultz, W., and Hayes, M., 2015, Seasonal ranges, migration, habitat use of the Platte Valley mule deer herd: Laramie, Wyo., Wyoming Cooperative Fish and Wildlife Research Unit.

Photograph from Gregory Nickerson.



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

Figure 31. Migration routes of the South Wind River mule deer herd.

Wyoming | Mule Deer

South Wind River Mule Deer Migration Routes

Mule deer within the South Wind River herd make short- and medium-distance migrations from the foothills near Lander, Wyoming, into the Wind River Range and around its southern flanks (fig. 31). The longest migration in this herd is a 75-mile (121-km) route originating south of Lander near Twin Creek. Deer following this long-distance route traverse the southern edge of the Wind River Range and summer in the mountainous terrain at the head of the Big Sandy River. Some deer make medium-distance migrations, traveling 14–51 mi (23–82 km) northwest of Sweetwater Station to summer range in the northern Great Divide Basin. Meanwhile, other deer in this population make short- and medium-distance migrations of 7–59 mi (11–95 km), moving along the Lander foothills and up into the Wind River Range. Challenges for South Wind River deer include navigating rugged terrain, crossing U.S. Highways 789 and 28, and navigating development in and around Lander.

Animal Capture and Data Collection

Sample size: 42 adult female mule deer
Relocation frequency: 2–24 hours
Project duration: 2012–2018

Data Analysis

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

Models derived from:

- Migration: 65 sequences from 28 individuals (32 spring and 33 fall sequences)
- Winter: 78 sequences from 42 individuals

Route Summary

Migration start and end date (median):

- Spring: May 4 to May 13
- Fall: October 7 to October 16

Days migrating (mean):

- Spring: 13 days
- Fall: 11 days

Migration route length:

- Min: 7 mi (11.3 km)
- Mean: 21 mi (33.8 km)
- Max: 75 mi (120.7 km)

Winter Use Summary

Winter use start and end date (median):

- December 28 to April 11

Days of winter use (mean): 70 days

Other Information

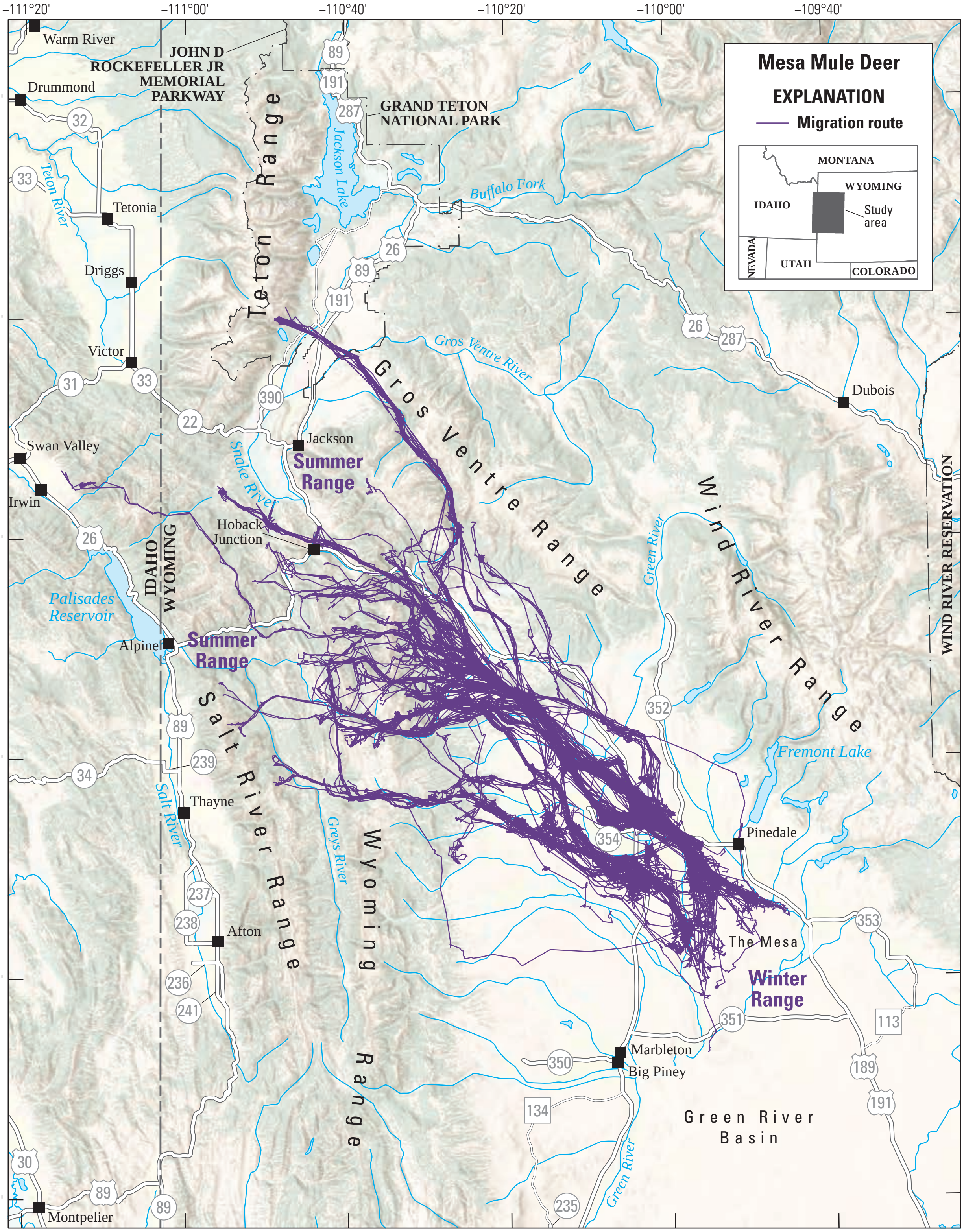
Project contacts:

- Matt Kauffman (mkauffm1@uwyo.edu), U.S. Geological Survey, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming
- Stan Harter (stan.harter@wyo.gov), Wildlife Biologist, Wyoming Game and Fish Department
- Daryl Lutz (daryl.lutz@wyo.gov), Wildlife Management Coordinator, Wyoming Game and Fish Department

Data analyst:

- Holly Copeland, Sr. Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming

Photograph from Scott Copeland.



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

Figure 32. Migration routes of the Mesa mule deer population.

Wyoming | Mule Deer

Sublette Herd: Mesa Mule Deer Migration Routes

The Mesa mule deer population is part of the larger Sublette herd that winters in the north-central portion of the Green River Basin, east of the Green River and west of U.S. Highway 191 (fig. 32). The Mesa wintering area supports 3,000 to 5,000 deer that migrate northwest to summer ranges in the Wyoming Range, Gros Ventre Range, and Salt River Range. The Mesa winter range, which has been fragmented by a large natural gas field, has experienced 30–40 percent declines in deer abundance since this development began. Mitigating winter range impacts continues to be a challenge for managers. These migratory deer have benefited from six underpasses and two overpasses constructed along U.S. Highway 191 in 2012; the project has reduced wildlife-vehicle collisions by 85 percent.

Animal Capture and Data Collection

Sample size: 143 adult female mule deer
Relocation frequency: 2–3 hours
Project duration: 2003–2018

Data Analysis

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

Models derived from:

- Migration: 263 sequences from 83 individuals
- Winter: 291 sequences from 143 individuals

Route Summary

Migration start and end date (median):

- Spring: March 31 to May 20
- Fall: November 6 to November 25

Days migrating (mean):

- Spring: 56 days
- Fall: 22 days

Migration route length:

- Min: 21 mi (33.8 km)
- Mean: 52 mi (83.7 km)
- Max: 107 mi (172.2 km)

Winter Range Summary

Winter start and end date (median):

- December 15 to March 15

Days of winter use (mean): 87 days

Other Information

Project contacts:

- Hall Sawyer (hsawyer@west-inc.com), Wildlife Biologist, WEST, Inc.
- Brandon Scurlock (brandon.scurlock@wyo.gov), Wildlife Management Coordinator, Wyoming Game and Fish Department

Data analysts:

- Hall Sawyer, Wildlife Biologist, WEST, Inc.
- Andrew Telander, Wildlife Biologist, WEST, Inc.

Reports and publications:

- Sawyer, H., Korfanta, N.M., Nielson, R.M., Monteith, K.L., and Strickland, D., 2017, Mule deer and energy development—Long-term trends of habituation and abundance: Global Change Biology, v. 23, no. 11, p. 4521–4529. [Also available at https://doi.org/10.1111/gcb.13711.]
- Sawyer, H., Kauffman, M.J., and Nielson, R.M., 2009a, Influence of well pad activity on the winter habitat selection patterns of mule deer: Journal of Wildlife Management, v. 73, p. 1052–1061. [Also available at https://doi.org/10.2193/2008-478.]
- Sawyer, H., Lebeau, C., and Hart, T., 2012, Mitigating roadway impacts to migratory mule deer—a case study with underpasses and continuous fencing: Wildlife Society Bulletin, v. 36, no. 3, p. 492–498. [Also available at https://doi.org/10.1002/wsb.166.]

Photograph from Mark Thonhoff.

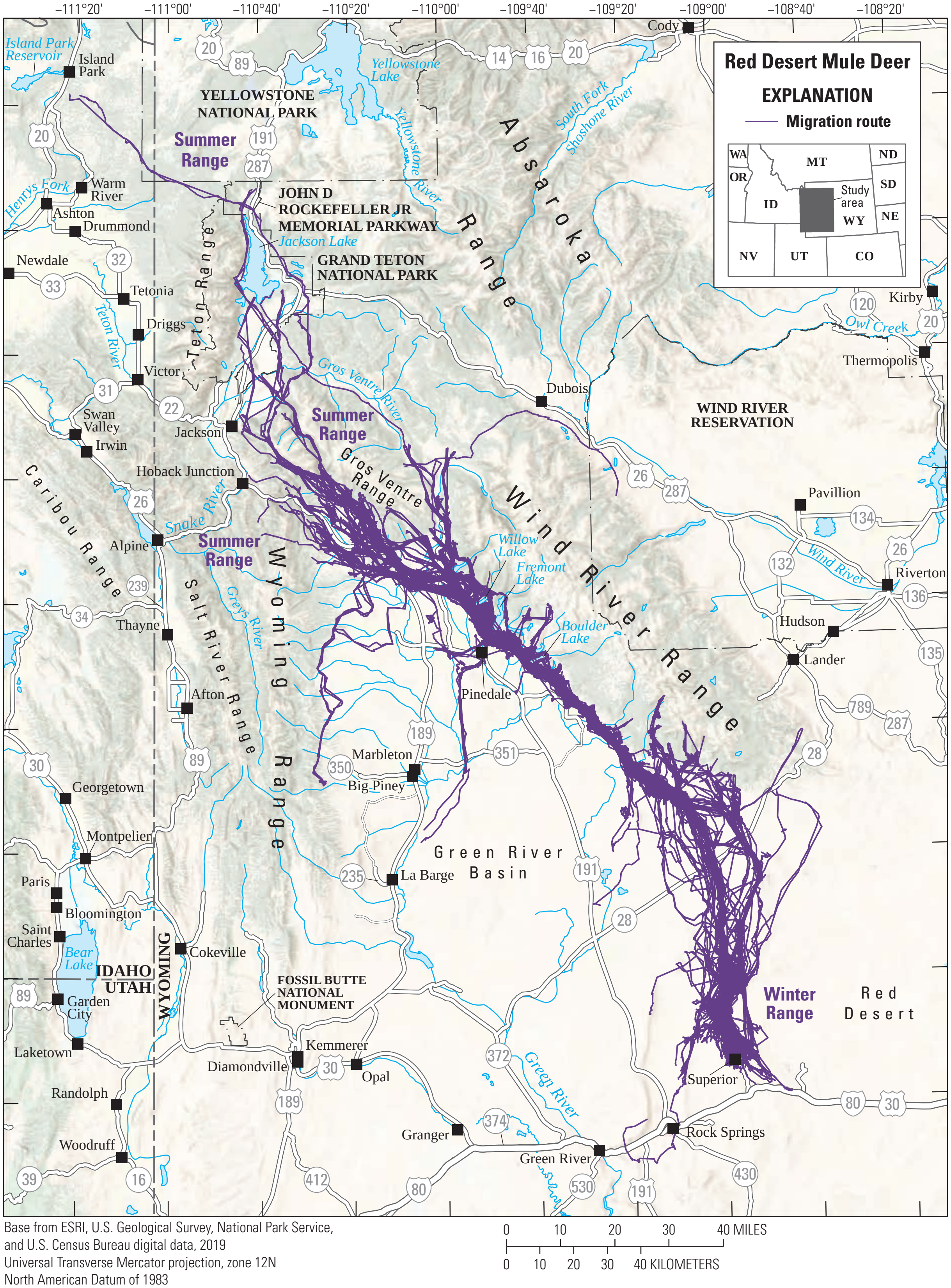


Figure 33. Migration routes of the Red Desert mule deer population.

Wyoming | Mule Deer

Sublette Herd: Red Desert Mule Deer Migration Routes

Mule deer within the Red Desert population, part of the larger Sublette herd, make the longest ungulate migration ever recorded in the lower 48 states (fig. 33). Here, mule deer travel an average one-way distance of 150 mi (241 km) from the Red Desert in the south to the Gros Ventre Range and Teton Range in the north. This migration originates in the desert sagebrush basins of the Red Desert area of southwest Wyoming where deer winter. In spring, an estimated 500 deer travel 50 mi (84 km) north across the desert to the west side of the Wind River Range. From there they merge with 4,000 to 5,000 other deer that winter in the foothills of the Wind River Range and then travel a narrow corridor along the base of the Wind River Range for 60 mi (97 km) before crossing the upper Green River Basin. Deer must navigate several bottlenecks, one as narrow as 50 m (164 ft) wide, at the outlets of Fremont, Willow, and Boulder Lakes. In the final leg of the journey, they travel another 30–50 mi (48–80 km) to individual summer ranges in the Gros Ventre Range.

Animal Capture and Data Collection

Sample size: 181 adult female mule deer
Relocation frequency: ~2 hours
Project duration: 2011–2019

Data Analysis

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

Models derived from:

- Migration: 392 sequences from 148 individuals (246 spring sequences, 143 fall sequences)
- Winter: 367 sequences from 172 individuals

Route Summary

Migration start and end date (median):

- Spring: April 25 to May 22
- Fall: October 14 to November 16

Average number of days migrating:

- Spring: 33 days
- Fall: 31 days

Migration route length:

- Min: 9 mi (14.5 km)
- Mean: 130 mi (209.2 km)
- Max: 255 mi (410.4 km)

Winter Use Summary

Winter use median start and end date:

- November 15 to April 15

Winter use length (mean): 98 days

Other Information

Project contacts:

- Hall Sawyer (hsawyer@west-inc.com), Wildlife Biologist, WEST, Inc.
- Matt Kauffman (mkauffm1@uwyo.edu), U.S. Geological Survey, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming
- Mark Zornes (mark.zornes@wyo.gov), Wildlife Management Coordinator, Green River Region, Wyoming Game and Fish Department
- Brandon Scurlock (brandon.scurlock@wyo.gov), Wildlife Management Coordinator Pinedale Region, Wyoming Game and Fish Department
- Sarah Dewey (sarah_dewey@nps.gov), Wildlife Biologist, National Park Service

Data analysts:

- Hall Sawyer, Wildlife Biologist, WEST, Inc.
- Andrew Telander, Wildlife Biologist, WEST, Inc.

Reports and publications:

- Sawyer, H., Hayes, M., Rudd, B., and Kauffman, M.J., 2014, The Red Desert to Hoback mule deer migration assessment, University of Wyoming.
- Sawyer, H., Middleton, A.D., Hayes, M.M., Kauffman, M.J., and Monteith, K.L., 2016, The extra mile: Ungulate migration distance alters the use of seasonal range and exposure to anthropogenic risk: Ecosphere, v. 7, no. 10. [Also available at https://doi.org/10.1002/ecs2.1534.]

Photograph from Joe Riis.

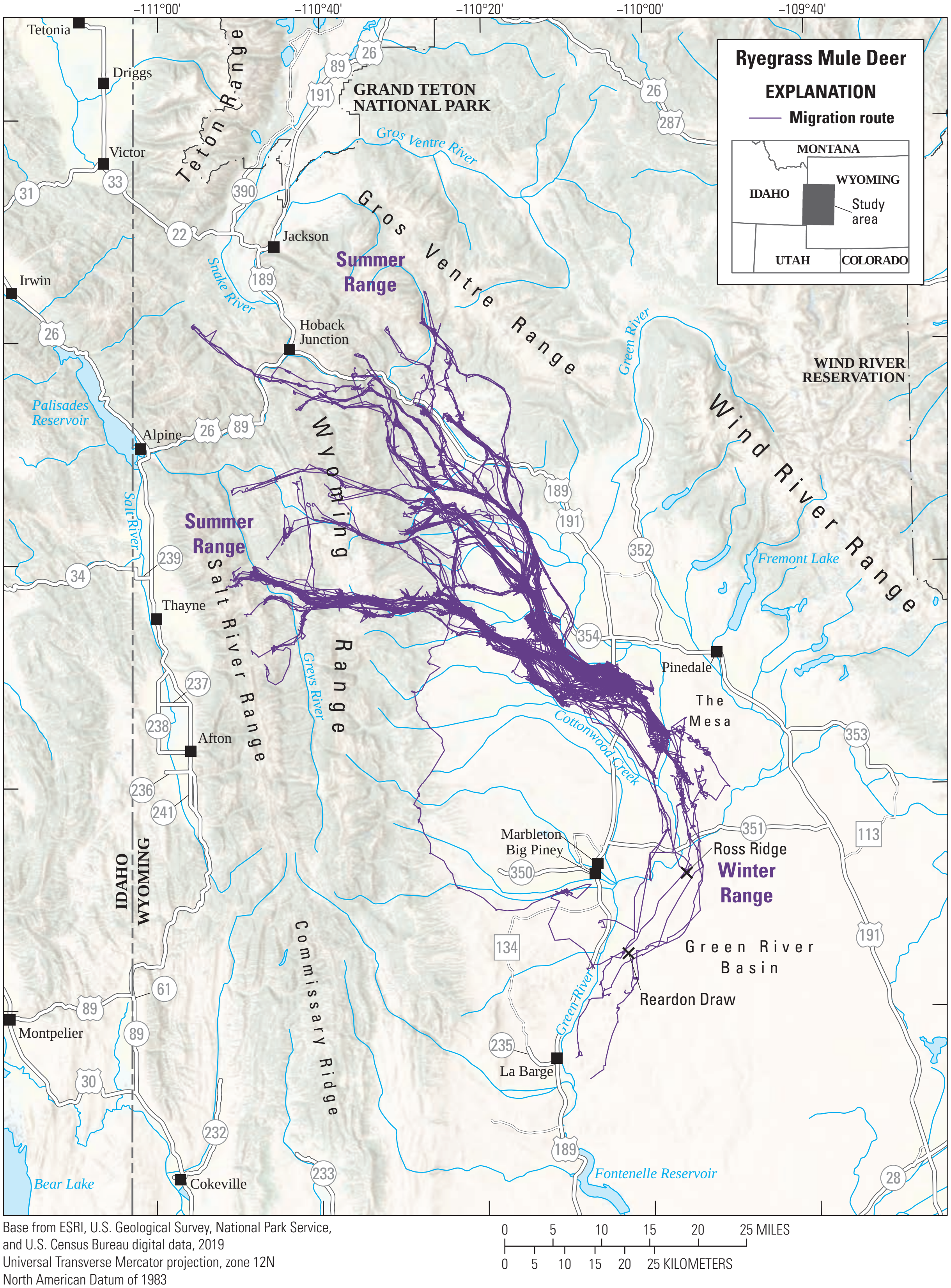


Figure 34. Migration routes of Ryegrass mule deer population.

Wyoming | Mule Deer

Sublette Herd: Ryegrass Mule Deer Migration Routes

The Ryegrass mule deer population is part of the larger Sublette herd that winters in the northwest portion of the Green River Basin, west of the Green River and north of Cottonwood Creek (fig. 34). In severe winters, these deer may travel southeast to The Mesa, Ross Ridge, or Reardon Draw areas. The Ryegrass region supports approximately 1,500 to 2,000 deer that migrate northwest to summer ranges in the Wyoming Range and Salt River Range. Many of these deer must traverse U.S. Highway 189, where deer-vehicle collisions are problematic. This stretch of highway is a top priority for underpass installation to improve both wildlife permeability and motorist safety.

Animal Capture and Data Collection

Sample size: 41 adult female mule deer
Relocation frequency: 2–3 hours
Project duration: 2007–2018

Data Analysis

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

Models derived from:

- Migration: 133 sequences from 33 individuals
- Winter: 96 sequences from 41 individuals

Route Summary

Migration start and end date (median):

- Spring: April 7 to May 23
- Fall: November 2 to November 26

Days migrating (mean):

- Spring: 48 days
- Fall: 26 days

Migration corridor length:

- Min: 23 mi (37.0 km)
- Mean: 47 mi (75.6 km)
- Max: 97 mi (156.1 km)

Winter Range Summary

Winter start and end date (median):

- December 15 to March 15

Days of winter use (mean): 87 days

Other Information

Project contacts:

- Hall Sawyer (hsawyer@west-inc.com), Wildlife Biologist, WEST, Inc.
- Brandon Scurlock (brandon.scurlock@wyo.gov), Wildlife Management Coordinator, Pinedale Region, Wyoming Game and Fish Department

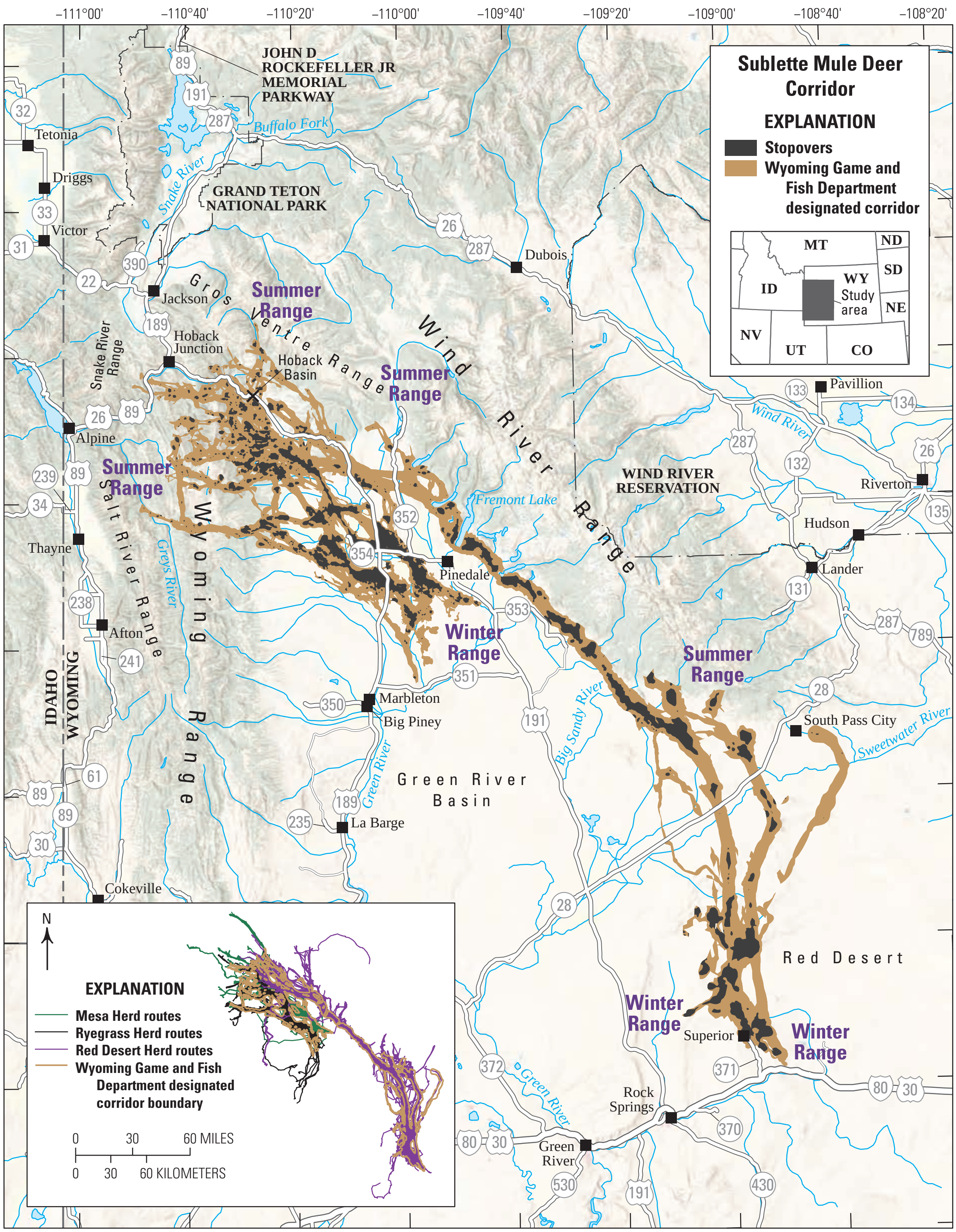
Data analysts:

- Hall Sawyer, Wildlife Biologist, WEST, Inc.
- Andrew Telander, Wildlife Biologist, WEST, Inc.

Reports and publications:

- Sawyer, H., Merkle, J.A., Middleton, A.D., Dwinnell, S.P.H., and Monteith, K.L., 2019, Migratory plasticity is not ubiquitous among large herbivores: Journal of Animal Ecology, v. 88, no. 3, p. 450–460. [Also available at https://doi.org/10.1111/1365-2656.12926]
- Copeland, H.E., Sawyer, H., Monteith, K.L., Naugle, D.E., Pocewicz, A., Graf, N., and Kauffman, M.J., 2014, Conserving migratory mule deer through the umbrella of sage-grouse: Ecosphere, v. 5, no. 9, p. 1–16. [Also available at http://doi.org/10.1890/ES14-00186.1.]

Photograph from Mark Thonhoff.



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

Figure 35. WGFD Designated Corridor, stopovers and routes of the mule deer herd.

Wyoming | Mule Deer

Sublette Herd: WGFD Designated Corridor

The Sublette Herd Corridor was designated by the Wyoming Game and Fish Department in 2016 (fig. 35). The Sublette Herd supports an estimated 20,000 to 25,000 animals, and the corridors represent movements from three subpopulations, including the Ryegrass, Mesa, and Red Desert segments. Deer from the Ryegrass winter west of the Green River and migrate northwest into portions of the Wyoming Range, Salt River Range, and Hoback Basin. Deer from the Mesa segment winter east of the Green River and migrate northwest to summer ranges in the Wyoming Range, Snake River Range, Hoback Basin, and Gros Ventre Range. Deer in the Red Desert occupy winter ranges near Superior, Wyo. just north of I-80. These animals migrate nearly 150 mi (241 km) between seasonal ranges, along a narrow corridor that leads across the Red Desert, along the base of the Wind River Range, and eventually into summer ranges around the Hoback Basin.

Corridor and Stopover Summary

Migration corridor area: 834,143 acres (337,565.7 ha) (WGFD designation)

Stopover area: 206,358 acres (83,510.1 ha)

Other Information

Agency contacts:

- Brandon Scurlock (brandon.scurlock@wyo.gov), Wildlife Management Coordinator, Pinedale Region, Wyoming Game and Fish Department
- Mark Zornes (mark.zornes@wyo.gov), Wildlife Management Coordinator, Green River Region, Wyoming Game and Fish Department

Data analyst:

- Hall Sawyer, Wildlife Biologist, WEST, Inc.

Reports and publications:

- Wyoming Game and Fish Department, 2017, Sublette mule deer migration corridor assessment: Cheyenne, Wyo., Wyoming Game and Fish Department.
- Sawyer, H., Middleton, A.D., Hayes, M.M., Kauffman, M.J., and Monteith, K.L., 2016, The extra mile: Ungulate migration distance alters the use of seasonal range and exposure to anthropogenic risk: Ecosphere, v. 7, no. 10. [Also available at https://doi.org/10.1002/ecs2.1534.]

Photograph from Joe Riis.

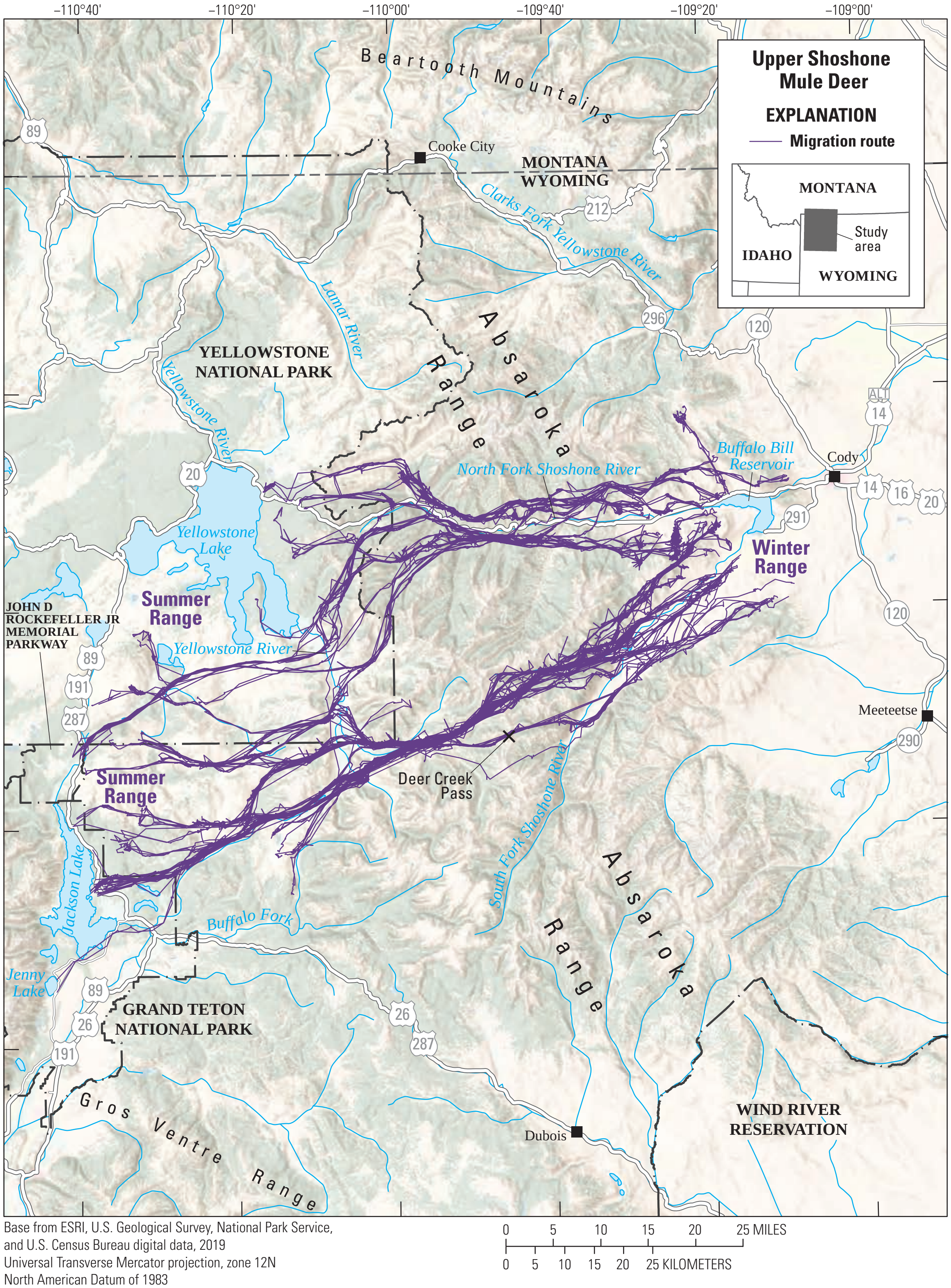


Figure 36. Migration routes of the Upper Shoshone mule deer herd.

Wyoming | Mule Deer

Upper Shoshone Mule Deer Migration Routes

Mule deer within the Upper Shoshone herd make a number of significant, long-distance migrations west into the core of the Greater Yellowstone Ecosystem (fig. 36). The longest is a 133-mile (214-km) migration that originates at the mouth of the South Fork of the Shoshone River near Buffalo Bill Reservoir and ends at Jenny Lake in Grand Teton National Park. Deer in the Upper Shoshone herd winter in the lower-elevation sagebrush valleys of the South Fork Shoshone River and North Fork of the Shoshone River. Each spring, an estimated 6,700 deer head west into the high-elevation, mountainous country of the Absaroka Range and then into Yellowstone National Park or Grand Teton National Park. These challenging journeys, an average of 53 mi (85 km) long, cross rugged terrain with fast-moving rivers and steep mountain passes. The highest is Deer Creek Pass at 10,800 ft (3,292 m) in elevation. These deer also navigate human-created obstacles, such as fences, housing developments, and U.S. Highway 16, a major road into Yellowstone National Park.

Animal Capture and Data Collection

Sample size: 59 adult female mule deer
Relocation frequency: ~2 hours
Project duration: 2016–2019

Data Analysis

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

Models derived from:

- Migration: 159 sequences from 56 individuals (79 spring sequences, 80 fall sequences)
- Winter: 142 sequences from 55 individuals

Route Summary

Migration start and end date (median):

- Spring: May 20 to June 7
- Fall: October 9 to October 29

Days migrating (mean):

- Spring: 21 days
- Fall: 23 days

Migration route length:

- Min: 14 mi (22.5 km)
- Mean: 74 mi (119.1 km)
- Max: 133 mi (214.0 km)

Winter Use Summary

Winter use start and end date (median):

- December 28 to May 3

Days of winter use (mean): 96 days

Other Information

Project contacts:

- Matthew Kauffman (mkauffm1@uwyo.edu), U.S. Geological Survey, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming
- Corey Class (corey.class@wyo.gov), Wildlife Management Coordinator, Wyoming Game and Fish Department
- Tony Mong (tony.mong@wyo.gov), Wildlife Biologist, Wyoming Game and Fish Department
- Sarah Dewey (sarah_dewey@nps.gov), Wildlife Biologist, National Park Service

Data analyst:

- Julien Fattebert, Post Doctoral Researcher, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming

Photograph from Scott Copeland.

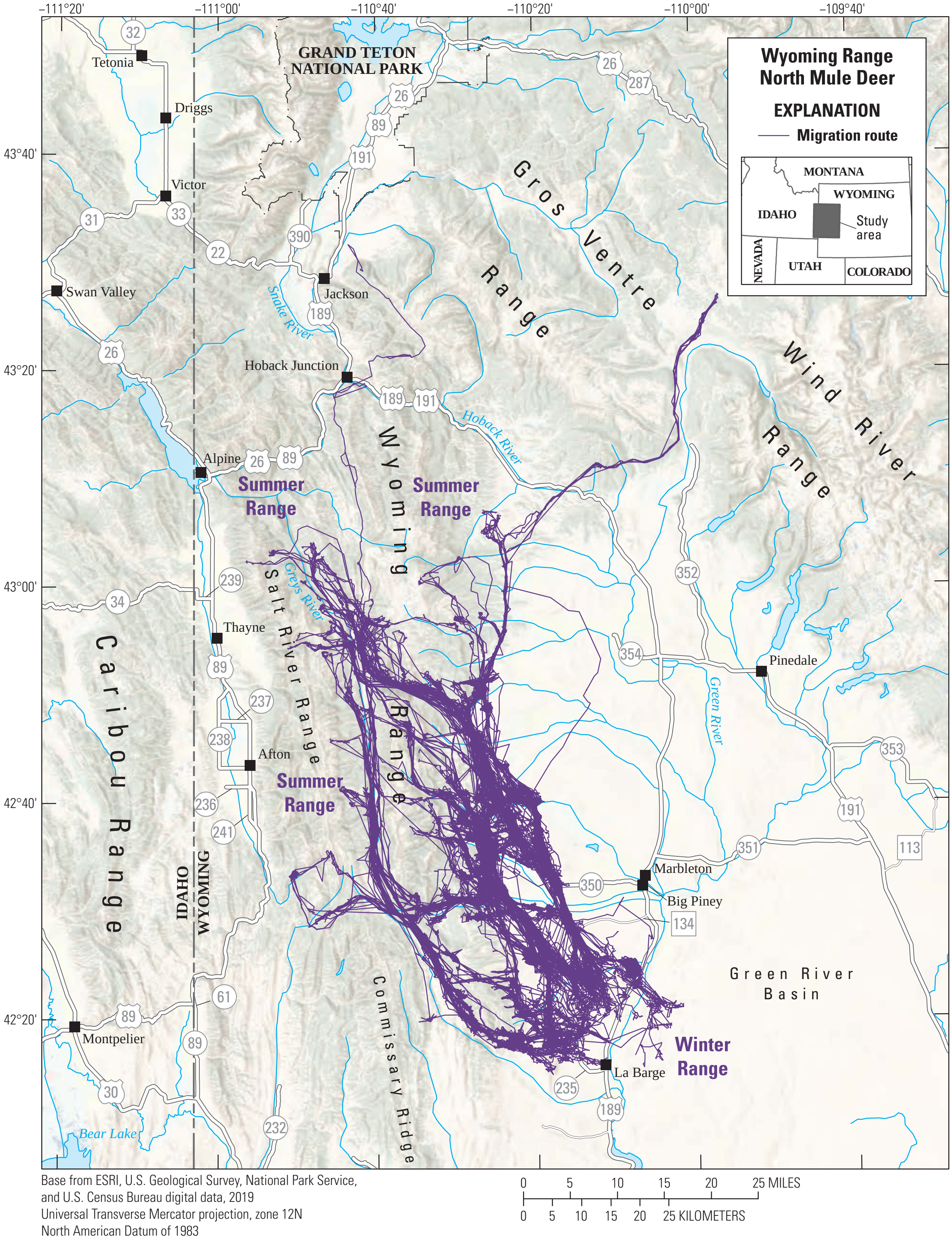


Figure 37. Migration routes of the Wyoming Range North mule deer population.

Wyoming | Mule Deer

Wyoming Range North Mule Deer Migration Routes

Mule deer in the northern Wyoming Range population use winter ranges in the area between Big Piney and LaBarge. During spring, these deer generally move northwesterly to high-elevation summer ranges in the Salt River and Wyoming Ranges (fig. 37). Interchange with deer in the Sublette herd unit has been documented, with some individuals migrating northwest into Upper Green River drainages. At least one individual migrated 85 mi (137 km) north and summered north of the town of Jackson. Challenges for Wyoming Range mule deer include energy development on winter ranges, vehicle collisions on U.S. Highway 189 between LaBarge and Big Piney, severe winters leading to high episodic mortality, and disease.

Animal Capture and Data Collection

Sample size: 63 adult female mule deer
Relocation frequency: 2–5 hours
Project duration: 2013–2018

Data Analysis

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

Models derived from:

- Migration: 271 sequences from 63 individuals (144 spring sequences, 127 fall sequences)
- Winter: 136 sequences from 65 individuals

Route Summary

Migration start and end date (median):

- Spring: April 22 to May 30
- Fall: October 17 to November 21

Days migrating (mean):

- Spring: 44 days
- Fall: 30 days

Migration route length:

- Min: 7 mi (11.3 km)
- Mean: 40 mi (64.4 km)
- Max: 85 mi (136.8 km)

Winter Use Summary

Winter use start and end date (median):

- Nov 21 to March 22

Days of winter use (mean): 121 days

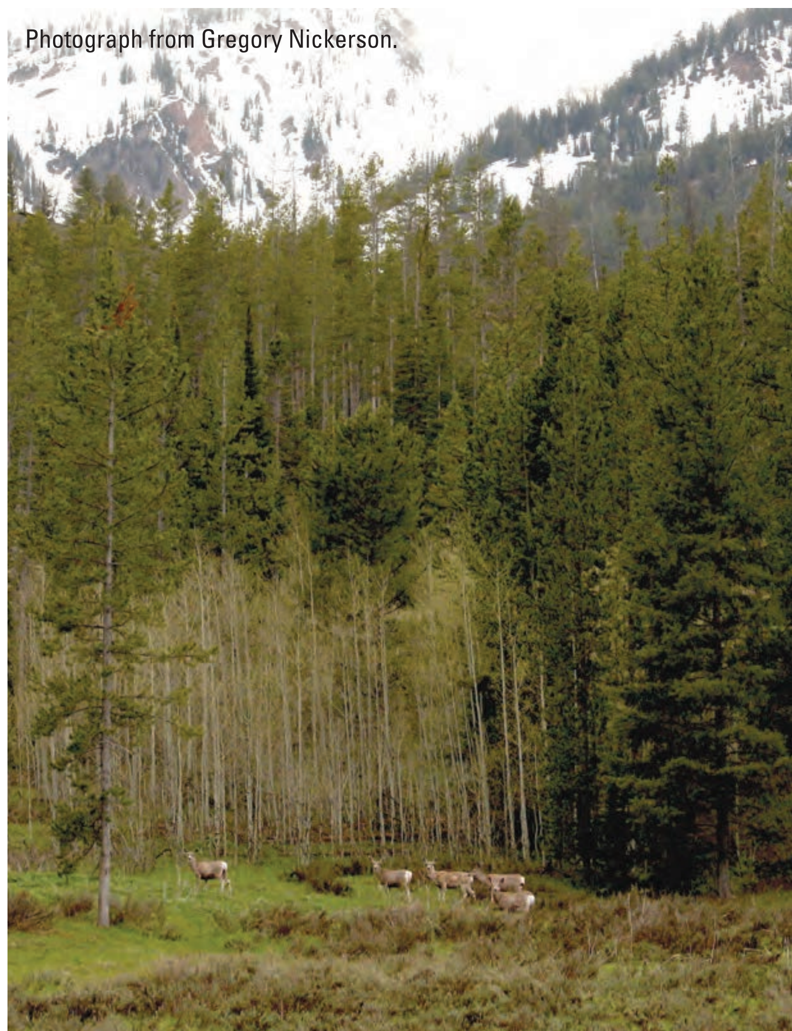
Other Information

Project contacts:

- Kevin Monteith (kevin.monteith@uwyo.edu), Associate Professor, University of Wyoming
- Gary Fralick (gary.fralick@wyo.gov) Wildlife Biologist, Wyoming Game and Fish Department

Reports and publications:

- Dwinnell, S.P.H., Sawyer, H., Randall, J.E., Beck, J.L., Forbey, J.S., Fralick, G.L., and Monteith, K.L., 2019, Where to forage when afraid—Does perceived risk impair use of the foodscape?: Ecological Applications, v. 29, no. 7. [Also available at https://doi.org/10.1002/eap.1972.]
- Jakopak, R.P., LaSharr, T.N., Dwinnell, S.P.H., Fralick, G.L., and Monteith, K.L., 2019, Rapid acquisition of memory in a complex landscape by a mule deer: Ecology, v. 100, no. 12. [Also available at https://doi.org/10.1002/ecy.2854.]
- Aikens, E.O., Kauffman, M.J., Merkle, J.A., Dwinnell, S.P.H., Fralick, G.L., and Monteith, K.L., 2017, The greenscape shapes surfing of resource waves in a large migratory herbivore: Ecology Letters, v. 20, no. 6, p. 741–750. [Also available at https://doi.org/10.1111/ele.12772.]


Photograph from Gregory Nickerson.

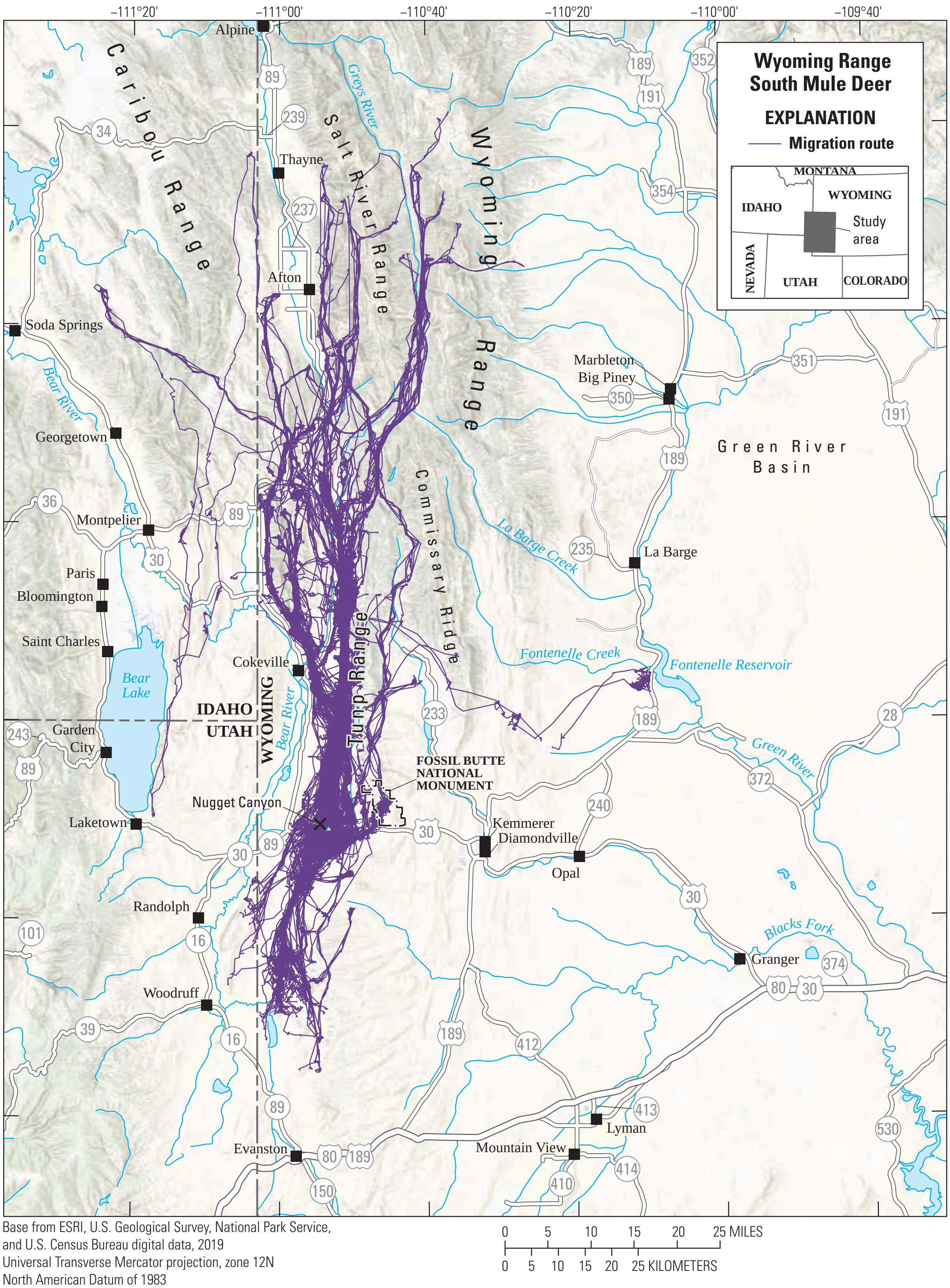


Figure 38. Migration routes of the Wyoming Range North mule deer population.

Wyoming | Mule Deer

Wyoming Range South Mule Deer Migration Routes

Mule deer in the southern Wyoming Range population winter north of Evanston in the relatively low mountains between Kemmerer, Wyoming, and Woodruff Narrows Reservoir along the Utah border (fig. 38). Many deer in this population migrate north more than 100 mi (161 km) to summer ranges in the Wyoming Range surrounding Afton, Wyoming. Migrations in this population are not limited to Wyoming, with at least one deer summering in the Caribou Range in Idaho. Challenges for this population include highway and train mortality, especially along U.S. Highway 30. A number of highway underpasses were constructed between 2001 and 2008 along U.S. Highway 30 at Nugget Canyon, which has significantly reduced vehicle-caused mortality.

Animal Capture and Data Collection

Sample size: 63 adult female mule deer
Relocation frequency: 2–5 hours
Project duration: 2013–2018

Data Analysis

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

Models derived from:

- Migration: 237 sequences from 63 individuals (129 spring sequences, 108 fall sequences)
- Winter: 140 sequences from 68 individuals

Route Summary

Migration start and end date (median):

- Spring: March 27 to May 17
- Fall: October 18 to December 5

Days migrating (mean):

- Spring: 50 days
- Fall: 37 days

Migration route length:

- Min: 9 mi (14.5 km)
- Mean: 50 mi (80.5 km)
- Max: 108 mi (173.8 km)

Winter Use Summary

Winter use start and end date (median):

- Nov 7 to Mar 19

Days of winter use (mean): 132 days

Other Information

Project contacts:

- Kevin Monteith (kevin.monteith@uwyo.edu), Assistant Professor, University of Wyoming
- Gary Fralick (gary.fralick@wyo.gov), Wildlife Biologist, Wyoming Game and Fish Department

Reports and publications:

- Dwinnell, S.P.H., Sawyer, H., Randall, J.E., Beck, J.L., Forbey, J.S., Fralick, G.L., and Monteith, K.L., 2019, Where to forage when afraid: Does perceived risk impair use of the foodscape?: Ecological Applications, v. 29, no. 7, p. e01972. [Also available at https://doi.org/10.1002/eap.1972.]
- Jakopak, R.P., LaSharr, T.N., Dwinnell, S.P.H., Fralick, G.L., and Monteith, K.L., 2019, Rapid acquisition of memory in a complex landscape by a mule deer: Ecology, v. 100, no. 12. [Also available at https://doi.org/10.1002/ecy.2854.]
- Aikens, E.O., Kauffman, M.J., Merkle, J.A., Dwinnell, S.P.H., Fralick, G.L., and Monteith, K.L., 2017, The greenscape shapes surfing of resource waves in a large migratory herbivore: Ecology Letters, v. 20, no. 6, p. 741–750. [Also available at https://doi.org/10.1111/ele.12772.]

Photograph from Brandon Scurlock, Wyoming Game and Fish Department.

Pronghorn

Pronghorn have been in North America for over a million years. Their scientific name, *Antilocapra americana*, means “American goat antelope” though they are neither from the goat or antelope family. Rather, they are the lone surviving member of the family Antilocapridae from the Pleistocene epoch (lasting from 2.6 million years to 11,700 years ago). They are uniquely suited to inhabit the open grasslands and sagebrush expanses of the American West. In these open environments, pronghorn evolved with the now-extinct saber-toothed cat (*Smilodon* spp.), evading predation by running at speeds up to 55 mi per hour (89 kilometers per hour). Consequently, they are still the fastest land mammal native to the western hemisphere (fig. 39).

Pronghorn have specific habitat requirements and rely on open grasslands and sagebrush systems with a variety of grasses, forbs (flowering plants), and shrubs. In Wyoming, the quality of winter range is important to pronghorn survival (Sawyer and others, 2005). In Wyoming, pronghorn occupy low-elevation sagebrush basins, preferring areas with high sagebrush density, as sagebrush is their primary winter forage (Sawyer and others, 2005). In the Southwest United States, moisture is an important component of habitat quality and is necessary for adequate forage and successful recruitment of fawns (Brown and Ockenfels, 2007).

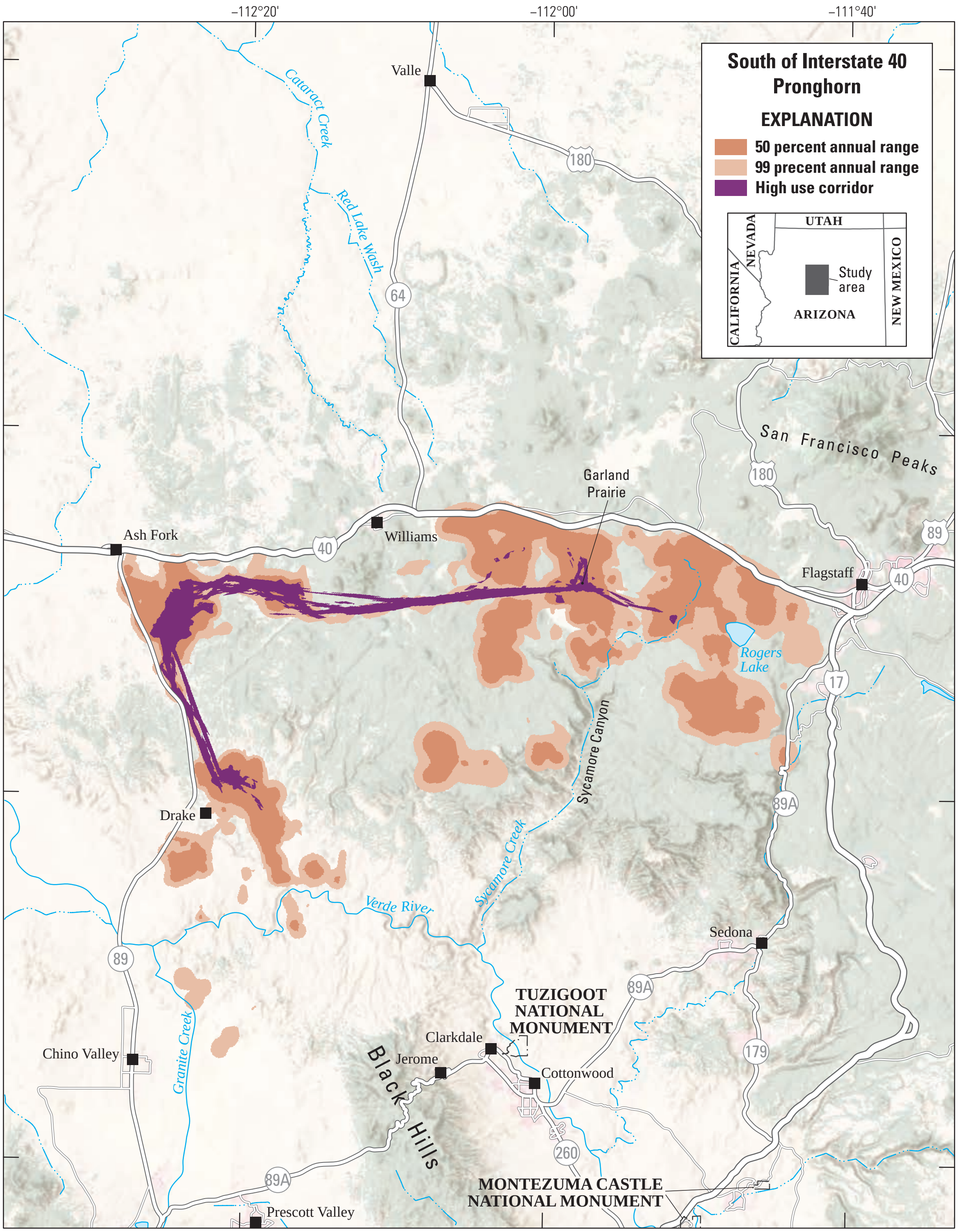
The movement patterns of pronghorn tend to be much broader and less predictable than other ungulate species. Pronghorn have a limited ability to navigate deep snow. Thus, they leave high-elevation summer ranges earlier than other ungulates to avoid getting caught in an early snowfall. In contrast to mule deer, which generally tend to use the same migratory routes year after year, pronghorn are facultative migrants, similar to bison and able to adapt their behavior depending on environmental conditions. Depending on factors such as snow depth, forage quality, and disturbance, pronghorn may migrate one year but not the next (Sawyer and others, 2005; Reinking and others, 2019). Further, many pronghorn populations contain a mix of resident, migratory, and nomadic individuals. Some of the more notable migratory populations include (1) the “Path of the Pronghorn,” on which animals move 150 mi (241 km) between Grand Teton National Park and the Upper Green River Basin (Berger, 2004), (2) the Northern Great Plains, where some pronghorn move nearly 250 mi (402 km) between seasonal ranges in Montana and Canada (Tack and others, 2019), and (3) the Southwest, where pronghorn in Arizona migrate up to 117 mi (189 km) between Garland Prairie and the Verde River Valley.

Pronghorn historically ranged across western North America from Canada to central Mexico and numbered in the millions (fig. 39). During the early 1900s, unregulated hunting drove their numbers to as low as 13,000. By the 1980s, sustained conservation and translocation efforts allowed their numbers to rebound to an estimated 800,000 pronghorn in western North America. Although still widely distributed, modern populations are smaller and more fragmented. Approximately 10,000 pronghorn inhabit Arizona and 400,000 reside in Wyoming. Pronghorn populations are struggling in some locations and, in Wyoming, population trends show local declines of more than 20 percent since 1996 (Reinking and others, 2019).

Pronghorn face several conservation challenges. Increasing human development has restricted the animals’ movement and connectivity, forcing pronghorn to navigate a web of fences, roads, and other anthropogenic disturbances (for example, energy development). Recent research has documented the negative impacts that fencing and energy development can have on pronghorn populations, including avoidance, winter range abandonment, and loss of connectivity (Sawyer and others, 2005; Jones and others, 2019; Reinking and others, 2019). Fences are the densest anthropogenic feature of the western landscapes and can present a significant movement barrier for pronghorn because they rarely jump over fences (Jones and others, 2018). Habitat loss also threatens pronghorn populations. In the Southwest, for example, moisture regimes and historic land-use practices have allowed juniper tree encroachment into former grasslands and savannahs, resulting in more fragmented blocks of pronghorn habitat (McKinney and others, 2008).

In this report, pronghorn migration and annual range has been mapped for one population in Arizona. Data collection and analyses for several pronghorn herds occupying other western states are ongoing and will be reported in future reports. Analytical methods for these data are provided in Appendix 1.

Figure 39. Current and historic range of pronghorn in western North America (Demarais and Krausman, 2000).



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

Figure 40. High use migration corridor and annual range of South of Interstate 40 Pronghorn population.

Arizona | Pronghorn

South of Interstate 40 Pronghorn Migration Corridor

Interest in the movement of pronghorn south of Arizona's Interstate 40 (I-40) began when telemetry data from 1999 to 2004 showed seasonal round-trip movements upwards of 100 mi (161 km) (fig. 40). In 2018, high-resolution GPS location data confirmed persistence of this remarkable pronghorn migration. This herd resides primarily in GMU 8, which had a population estimate of 400 individuals in 2019. Unlike traditional summer-winter range dynamics, this pronghorn population uses a complex of several important seasonal ranges during their annual movements. These seasonal ranges are connected by narrow corridors. 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 the Garland Prairie area. During migration, animals move westward, parallel to I-40. Migrating pronghorn first pass through densely forested habitat, then grasslands near Ash Fork, and finally move south to winter range near Drake, Ariz. In late March, the migration is reversed. High-volume roads including I-40 and State Route 89 present the largest impediments to movement for this migration. These roads also appear to determine the herd's movement patterns along this corridor, as pronghorn rarely cross them.

Animal Capture and Data Collection

Sample size: 15 female/6 male adult pronghorn
Relocation frequency: ~3 hours
Project duration: 2018–2019

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: 34 sequences from 21 individuals (21 spring sequences, 13 fall sequences)

Corridor and Stopover Summary

Migration start and end date (median):

- Spring: March 17 to March 31
- Fall: November 4 to December 22

Days migrating (mean):

- Spring: 18 days
- Fall: 80 days

Migration corridor length:

- Min: 20 mi (32.2 km)
- Mean: 60 mi (96.6 km)
- Max: 118 mi (189.9 km)

Migration corridor area:

- 24,774 acres (10,025.7 ha) (high use)

Annual Range Summary

Start and end date (median):

- October 24, 2018 to November 1, 2019

Annual range (50 percent contour) area: 106,875 acres (43,250.8 ha)

Annual range (99 percent contour) area: 212,350 acres (85,935.0 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., J. W. Gagnon, S. C. Sprague, S. Boe, and R. E. Schweinsburg. 2011. Assessment of pronghorn movements and strategies to promote highway permeability: U.S. Highway 89. Final project report 619, Arizona Department of Transportation Research Center, Phoenix, Ariz.
- 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.

Photograph from Scott Sprague.

Elk

Elk currently range from Canada to the southern U.S. border and have also been reintroduced in small parts of their historic range across the eastern United States (fig. 41). They are one of the largest terrestrial mammals in North America and prefer a mix of forested habitat that provides cover and large, open areas for foraging, although they can also thrive in open sagebrush habitat. Elk are primarily grazers, consuming an average of 20 pounds (lb; 9 kilograms [kg]) of food per day. Elk feed preferentially on grasses and forbs, though they often switch to woody shrubs in winter (Toweill and others, 2002). Forests provide security cover that protects elk from predators and hunting. These habitats are especially important during the very early calf-rearing period. During early calf rearing, maternal elk with their calves are solitary before forming nursery groups with other adult females and their calves (Altmann, 1952). Older females have also been documented seeking out heavy forest cover during hunting season (Thurfjell and others, 2017).

The breeding season occurs during late summer or early fall, when elk gather in mixed groups of females with calves and a few males. Males are renowned for their complex vocalizations, called bugling, which they make during breeding (Toweill and others, 2002). In the fall, these haunting sounds echo through the landscape.

While most elk are seasonally migratory, the tule elk of coastal California and the Roosevelt elk of Oregon and Washington generally do not migrate (or they migrate comparatively less than Rocky Mountain elk). Because their preferred habitat and weather conditions remain relatively constant year-round, they have less need to migrate (Toweill and others, 2002). In regions that experience high snowfall and more severe winter conditions, Rocky Mountain elk typically winter in consolidated groups at lower elevations and migrate in various-sized groups to higher elevations once the snow melts (Altmann, 1952; Morgantini and Hudson, 1988).

Loss and fragmentation of winter range due to development, fencing, agriculture, and other intensive land uses threaten elk populations, and some states have implemented winter feeding programs as a result. Like many other large herbivores worldwide, these human influences have also impacted natural migratory behaviors of elk. Some populations have changed the patterns and timing of their migrations or have lost their migratory behavior altogether (Berg and others, 2019). As is observed in other elk subspecies, some Rocky Mountain elk have more recently developed resident behavior in habitats where it is more beneficial for them to do so. For example, irrigated crops and supplemental feeding can entice animals to stay longer or even year-round on low-elevation winter range rather than needing to migrate to their traditional summer range (Barker and others, 2018).

Prior to European settlement, an estimated 10 million elk ranged across the United States and parts of Canada; this was the largest range of any cervid in North America. European settlement, unregulated hunting, and habitat destruction severely reduced elk numbers to less than 100,000 individuals in the early 1900s. Only four subspecies have survived: *Cervus canadensis roosevelti* (Roosevelt elk), *Cervus canadensis nelsoni* (Rocky Mountain elk), *Cervus canadensis nannodes* (tule elk), and *Cervus canadensis manitobensis* (Manitoban elk). Two other subspecies, *Cervus canadensis canadensis* (Eastern elk) and *Cervus canadensis merriami* (Merriam's elk), became extinct. Yellowstone National Park harbored one of the few remaining viable Rocky Mountain elk populations, and as early as 1912, elk from the park were reintroduced to locations all across the West (Evans, 1939).

Protection from hunting and the near-eradication of large predators enabled a rapid recovery of elk populations (Mac and others, 1998). Today, approximately one million elk inhabit the western United States, a handful of central and eastern states, and Canada (Rocky Mountain Elk Foundation, 2020). Colorado is home to the largest elk population, followed by Montana, Idaho, and Oregon (Colorado Parks & Wildlife, 2020; Idaho Department of Fish and Game, 2020; Montana Fish Wildlife & Parks, 2020; Oregon Department of Fish & Wildlife, 2020).

In this report, elk migrations have been mapped for Arizona and Wyoming. The mapping of corridors, routes, stopovers, and winter ranges follows a standard procedure as described by Sawyer and others (2009b). Details are given in the summary statistics associated with each map. The analytical methods common to all analyses, including those specific to each state, are provided in Appendix 1. For Wyoming herds, elk corridors have not been officially designated by the state; only the routes (in other words, lines) are shown in the associated maps.

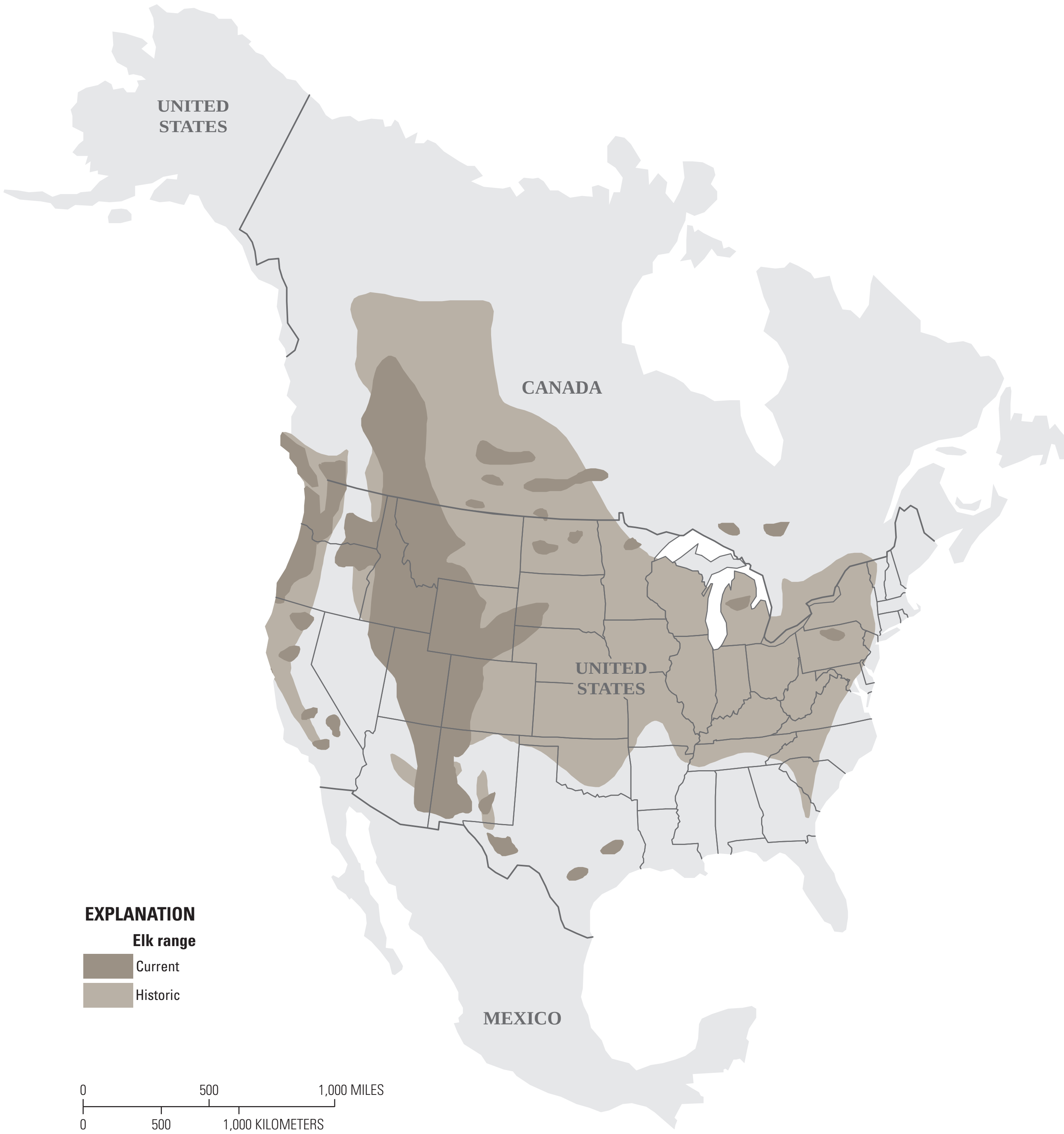


Figure 41. Current and historic range of elk in North America (Demarais and Krausman, 2000).

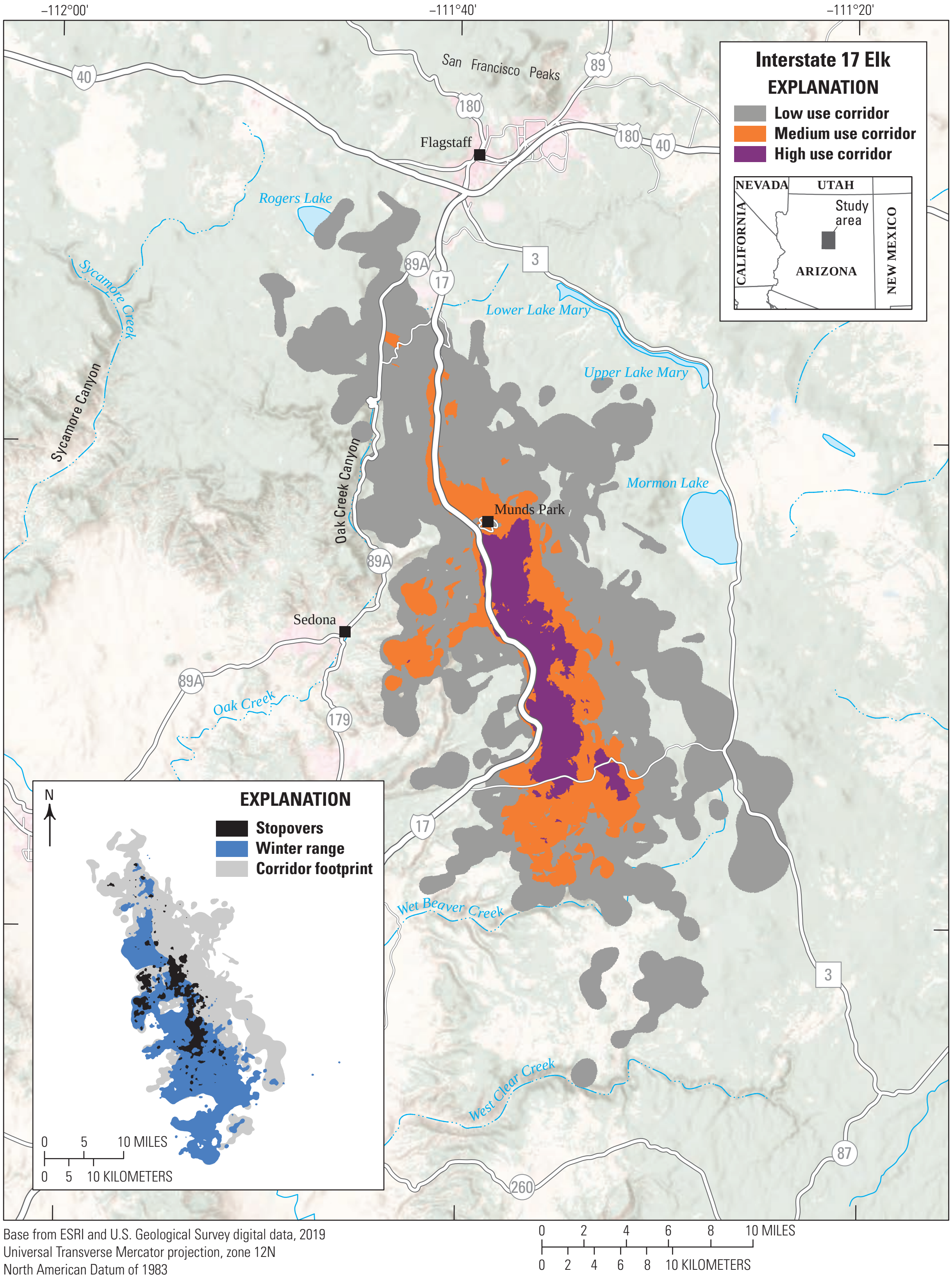


Figure 42. Migration corridors, stopovers and winter range of the Interstate 17 elk herd.

Arizona | Elk

Interstate 17 Elk Herd Migration Routes

The Interstate 17 (I-17) elk herd primarily resides in Arizona's GMUs 6A and 11M south of Flagstaff. The population estimate for elk in GMU 6A was 6,500 in 2019. Their summer range consists of gentle topography with ponderosa pine forest and interspersed riparian-meadow habitat. Annually, the I-17 elk herd migrates an average of 24 mi (39 km) to lower-elevation winter range dominated by pinyon-juniper habitat (fig. 42). This winter habitat is located along Oak Creek Canyon to the west and Wet Beaver Creek to the south. The I-17 elk herd faces high road mortality, averaging around 80 mortalities from vehicles per year (Gagnon et al 2013). Despite the high incidence of elk-vehicle collisions along I-17, road crossings are generally limited by the highway's high traffic volumes.

Animal Capture and Data Collection

Sample size: 35 female/12 male adult elk
Relocation frequency: ~2 hours
Project duration: 2006–2014

Data Analysis

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

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

Models derived from:

- Migration: 106 sequences from 47 individuals (55 spring sequences, 51 fall sequences)
- Winter: 60 sequences from 44 individuals

Corridor and Stopover Summary

Migration start and end date (median):

- Spring: March 14 to March 27
- Fall: December 5 to December 19

Average number of days migrating:

- Spring: 18 days
- Fall: 18 days

Migration corridor length:

- Min: 7 mi (11.3 km)
- Mean: 24 mi (38.6 km)
- Max: 58 mi (93.3 km)

Migration corridor area:

- 429,139 acres (173,666.4 ha) (low use)
- 72,672 acres (29,409.3 ha) (medium use)
- 17,890 acres (7,239.8 ha) (high use)

Stopover area: 22,165 acres (8,969.9 ha)

Winter Range Summary

Winter start and end date (median):

- December 13 to March 13

Winter length (mean): 88 days
Winter range (50 percent contour) area: 122,290 acres (49,489.0 ha)

Other Information

Project contact:

- 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:

- Gagnon, J.W., Dodd, N.L., Sprague, S.C., Nelson, R., Loberger, C., Boe, S., and Schweinsburg, R.E., 2013, Elk movements associated with a high-traffic highway: Interstate 17: Phoenix, Ariz., Arizona Game and Fish Department.
- Gagnon, J. W., N. L. Dodd, S. C. Sprague, R. E. Nelson, C. D. Loberger, S. Boe, and R. E. Schweinsburg. 2013. Elk movements associated with a high-traffic highway: Interstate 17. Final project report 647, Arizona Department of Transportation Research Center, Phoenix, Ariz.

Photograph from Scott Sprague.

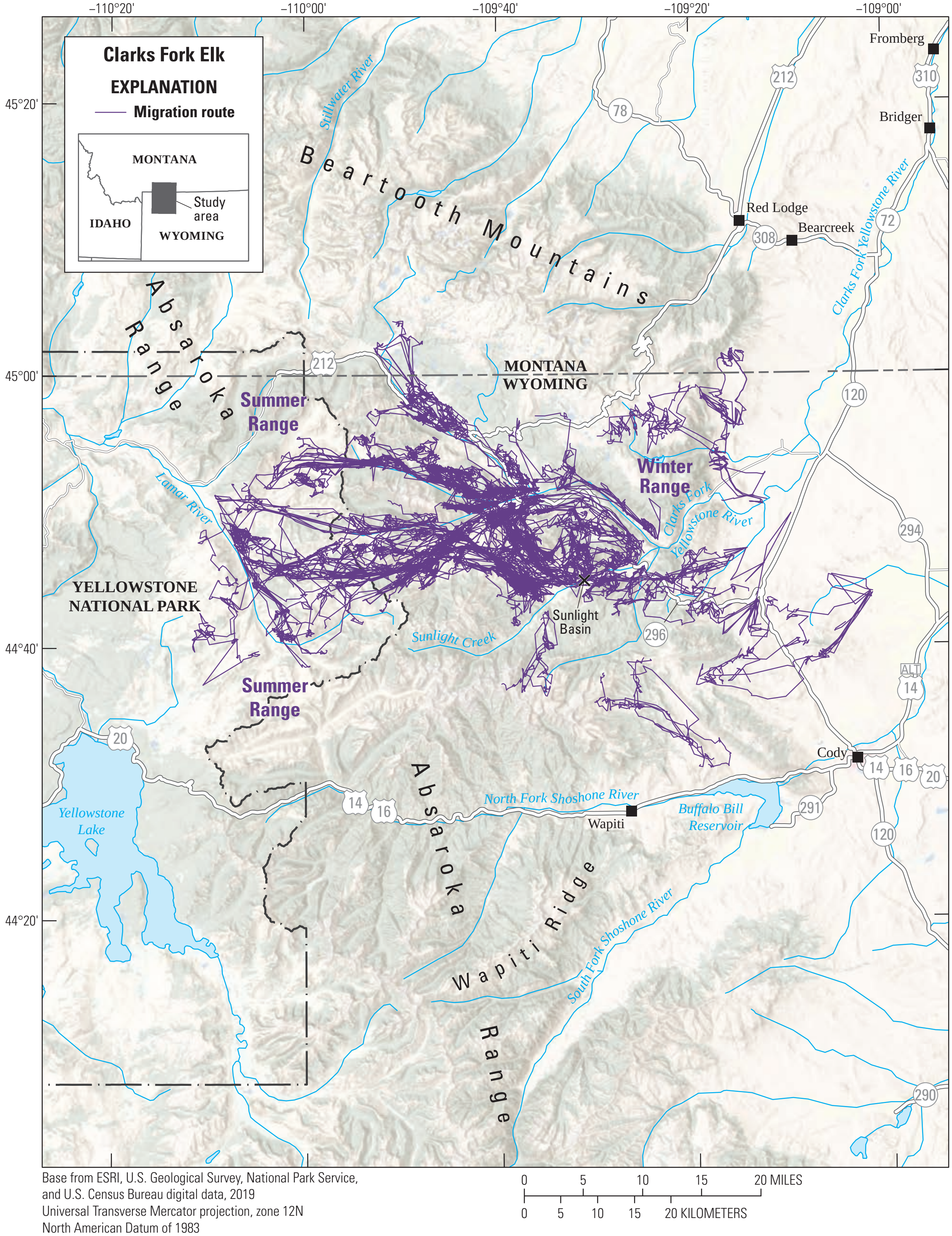


Figure 43. Migration routes of the Clarks Fork elk herd.

Wyoming | Elk

Clarks Fork Elk Migration Routes

Elk within the Clarks Fork herd migrate through some of the most rugged and remote terrain in the lower 48 states. The herd, which numbers around 3,000, winters in the Sunlight Basin and the Absaroka Range foothills just west of Cody, Wyo. (fig. 43). Winter ranges are a mix of sagebrush hills and lodgepole pine forests within expansive private ranchlands. During migration, animals travel an average one-way distance of 33 mi (53 km), with some animals migrating as far as 67 mi (108 km). In spring, the elk migrate off of winter range and head west towards Yellowstone National Park. They traverse up several drainages that flow out of the Absaroka Range, including the Clarks Fork of the Yellowstone River, Sunlight Creek, and smaller creeks to the south. Summer ranges consist of alpine and subalpine meadows embedded within spruce-fir and lodgepole pine forest that are predominately within the Park. The Clarks Fork herd is partially migratory, with migrants and resident animals mixing on winter range (residents tend to winter along the foothills further east). Since 2010, the migratory segment has seen poor recruitment due to drought and increased rates of predation by grizzly bears and wolves, while resident animals have been more productive and continue to expand to the east. Aside from the poor recruitment, the migrations are relatively safe because most of the routes traverse lands within the National Forest or National Park system.

Animal Capture and Data Collection

Sample size: 69 adult female elk
Relocation frequency: ~3 hours
Project duration: 2007–2010

Data Analysis

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

Models derived from:

- Migration: 107 sequences from 46 individuals (35 spring sequences, 72 fall sequences)
- Winter: 136 sequences from 66 individuals

Route Summary

Migration start and end date (median):

- Spring: June 2 to June 30
- Fall: October 21 to November 23

Days migrating (mean):

- Spring: 25 days
- Fall: 36 days

Migration route length:

- Min: 12 mi (19.3 km)
- Mean: 33 mi (53.1 km)
- Max: 67 mi (107.8 km)

Winter Use Summary

Winter use start and end date (median):

- January 16 to April 16

Days of winter use (mean): 85 days

Other Information

Project contacts:

- Arthur Middleton (amiddleton@berkeley.edu), University of California Berkeley
- Corey Class (corey.class@wyo.gov), Wildlife Management Coordinator, Wyoming Game and Fish Department

Data analyst:

- Matthew Cuzzocreo, Sr. Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming

Reports and publications:

- Middleton, A.D., Kauffman, M.J., McWhirter, D.E., Cook, J.G., Cook, R.C., Nelson, A.A., Jimenez, M.D., and Klaver, R.W., 2013, Animal migration amid shifting patterns of phenology and predation—Lessons from a Yellowstone elk herd: Ecology, v. 94, no. 6, p. 1245–1256. [Also available at https://doi.org/10.1890/11-2298.1.]
- Nelson, A.A., Kauffman, M.J., Middleton, A.D., Jimenez, M.D., McWhirter, D.E., Barber, J., and Gerow, K., 2012, Elk migration patterns and human activity influence wolf habitat use in the Greater Yellowstone Ecosystem: Ecological Applications, v. 22, no. 8, p. 2293–2307. [Also available at https://doi.org/10.1890/11-1829.1.]

Photograph from Travis Zaffarano.

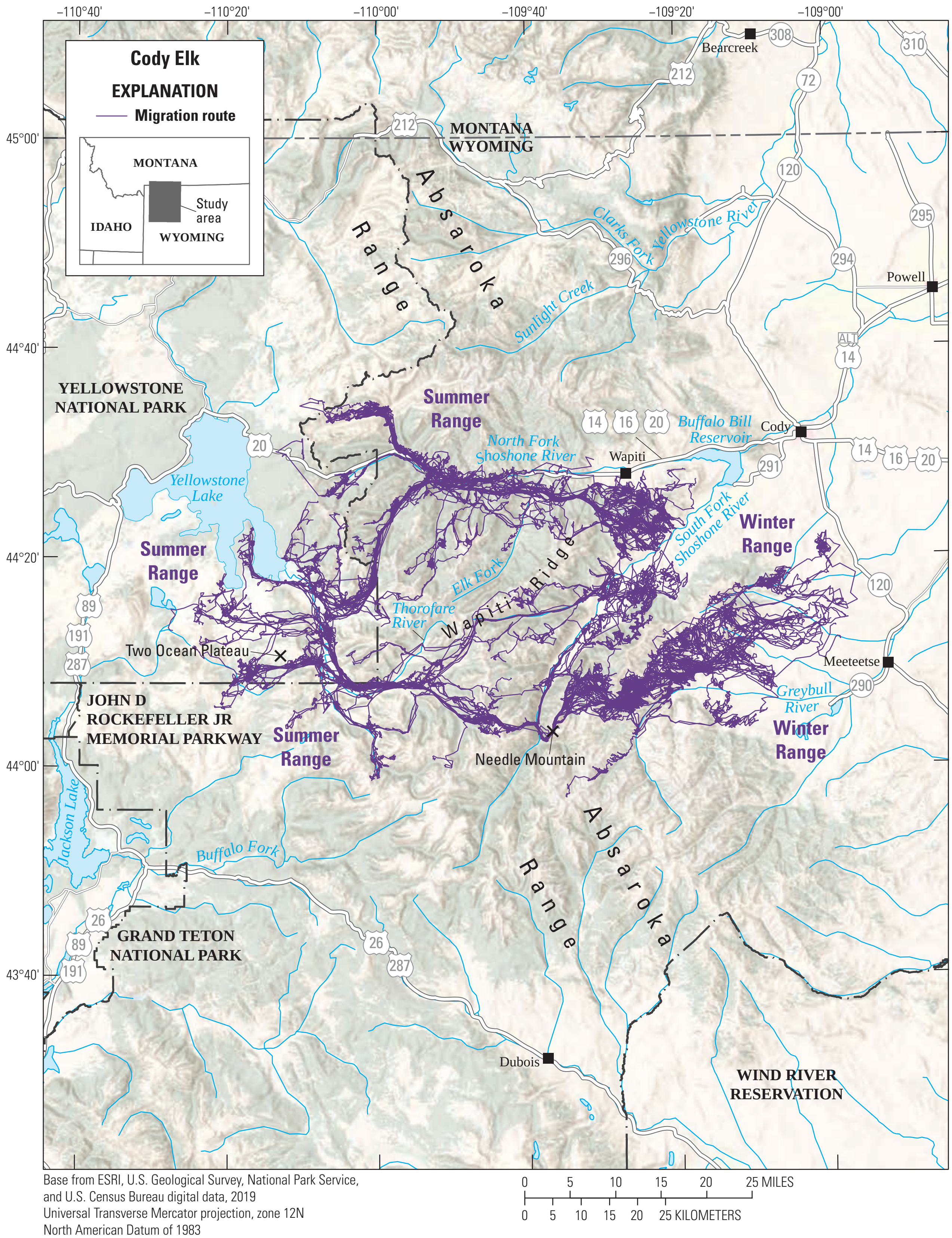


Figure 44. Migration routes of the Cody elk herd.

Wyoming | Elk

Cody Elk Migration Routes

The Cody elk herd migrates across rugged country on the eastern side of the Absaroka Range near Cody, Wyo. This large herd of 6,000–7,000 animals winters in foothill habitat to the south and west of Cody (fig. 44). There are three core winter areas, namely the valleys formed by the North and South Fork of the Shoshone River and the headwaters of the Greybull River north to Meeteetse Creek. In spring, the elk that winter along the North Fork of the Shoshone generally follow the river west towards the Park, some of them branching up Elk Fork and other tributaries. The elk that winter in the South Fork of the Shoshone follow it upstream in spring, eventually heading west up into the Thorofare Creek drainage and Yellowstone National Park. The elk that winter in the upper Greybull River drainage also summer in the Thorofare Creek drainage, but their journey is more arduous. From winter range, they climb nearly 3,000 vertical ft (914 m), up and over Needle Mountain, before descending to the Shoshone River, only to climb out of the river again and move up to the Thorofare for summer. Some animals in this herd make migrations as far as 117 mi (188 km), while others make shorter migration; the mean migration length is 58 mi (93 km). Like the Clarks Fork herd, this herd is also partially migratory, with resident animals typically exhibiting higher levels of calf recruitment. Because most of the migrations of this herd cross public forest and park land, the most pressing management issue is to maintain strong collaborative relationships with the owners of large land holdings that privately manage much of the winter range these elk return to each autumn.

Animal Capture and Data Collection

Sample size: 29 adult female elk
Relocation frequency: ~1 hour
Project duration: 2014–2017

Data Analysis

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

Models derived from:

- Migration: 109 sequences from 28 individuals (63 spring sequences, 46 fall sequences)
- Winter: 46 sequences from 20 individuals

Route Summary

Migration start and end date (median):

- Spring: May 14 to June 24
- Fall: October 26 to November 29

Days migrating (mean):

- Spring: 41 days
- Fall: 46 days

Migration route length:

- Min: 19 mi (30.6 km)
- Mean: 58 mi (93.3 km)
- Max: 117 mi (188.3 km)

Winter Use Summary

Winter use start and end date (median):

- January 14 to April 10

Days of winter use (mean): 64 days

Other Information

Project contacts:

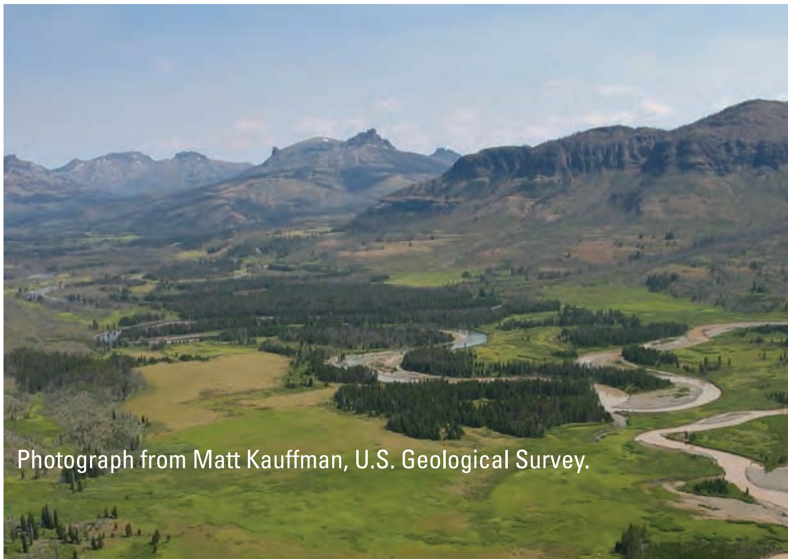
- Arthur Middleton (amiddleton@berkeley.edu), University of California Berkeley
- Matt Kauffman (mkauffm1@uwyo.edu), U.S. Geological Survey, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming
- Corey Class (corey.class@wyo.gov), Wildlife Management Coordinator, Wyoming Game and Fish Department

Data analyst:

- Matthew Cuzzocreo, Sr. Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming

Reports and publications:

- Nelson, A.A., Kauffman, M.J., Middleton, A.D., Jimenez, M.D., McWhirter, D.E., and Gerow, K., 2016, Native prey distribution and migration mediates wolf (*Canis lupus*) predation on domestic livestock in the Greater Yellowstone Ecosystem: Canadian Journal of Zoology, v. 94, no. 4, p. 291–299. [Also available at https://doi.org/10.1139/cjz-2015-0094.]



Photograph from Matt Kauffman, U.S. Geological Survey.

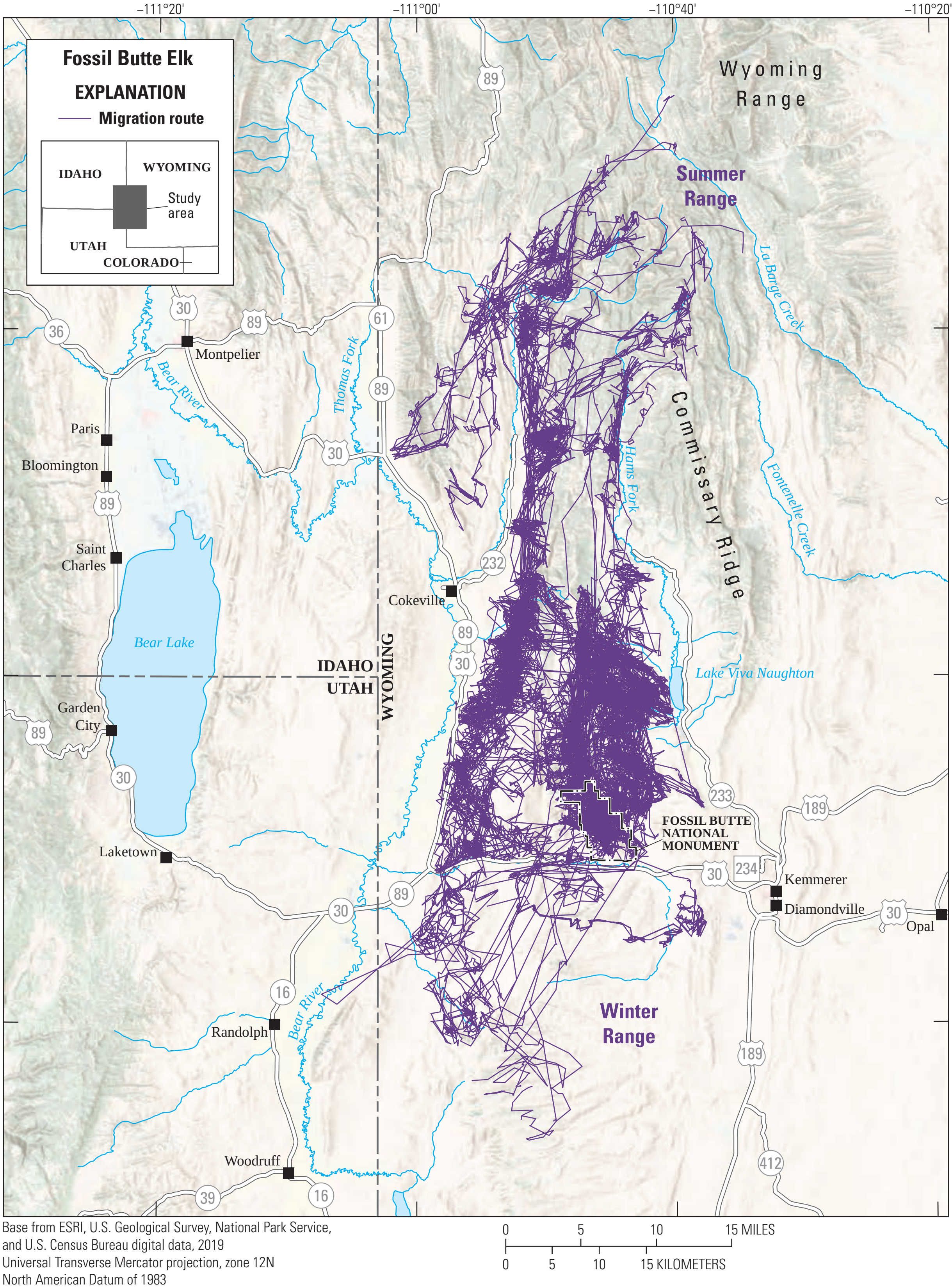


Figure 45. Migration routes of the Fossil Butte elk population.

Wyoming | Elk

Fossil Butte Elk Migration Routes

The Fossil Butte (hereafter referred to as the Monument in this section of the report) elk population winters in the southern Wyoming Range between Fossil Butte National Monument and Cokeville (fig. 45). During spring, they migrate north short (11 mi [18 km]) to medium (74 mi [119 km]) distances. The segment of the elk population that winters near the Monument migrates into the Wyoming Range at the head of the Hams Fork and LaBarge Creek. This population departs their summer ranges during the beginning of archery season in early fall for the Monument, where no hunting is allowed. Elk wintering closer to Cokeville migrate north in the spring along the western edge of the Wyoming Range. Cokeville collared elk departed their summer ranges later in the season, timed with weather events and vegetation senescence. Challenges to this elk herd include crossing U.S. Highway 89.

Animal Capture and Data Collection

Sample size: 75 adult female elk
Relocation frequency: ~5 hours
Project duration: 2005–2010

Data Analysis

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

Models derived from:

- Migration: 207 sequences from 72 individuals (117 spring sequences, 90 fall sequences)
- Winter: 164 sequences from 75 individuals

Route Summary

Migration start and end date (median):

- Spring: April 15 to May 11
- Fall: August 11 to October 2

Days migrating (mean):

- Spring: 35 days
- Fall: 17 days

Migration route length:

- Min: 11.0 mi (17.7 km)
- Mean: 29.6 mi (47.6 km)
- Max: 74.9 mi (120.5 km)

Winter Use Summary

Winter use start and end date (median):

- January 6 to March 8

Days of winter use (mean): 61 days

Other Information

Project contacts:

- Tabitha Graves (tgraves@usgs.gov), Research Ecologist, U.S. Geological Survey, Northern Rocky Mountain Science Center, West Glacier, Montana
- Gary Fralick (gary.fralick@wyo.gov), Wildlife Biologist, Wyoming Game and Fish Department

Data analyst:

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

Reports and publications:

- Graves, T.A., Mikle, N.L., and Olexa, E.M., 2018, West Green River elk herd locations in southwestern Wyoming, 2005–2010—U.S. Geological Survey data release: Denver, Colo., U.S. Geological Survey.
- Mikle, N.L., Graves, T.A., and Olexa, E.M., 2019, To forage or flee—Lessons from an elk migration near a protected area: Ecosphere, v. 10, no. 4. [Also available at https://doi.org/10.1002/ecs2.2693.]

Photograph from National Park Service.

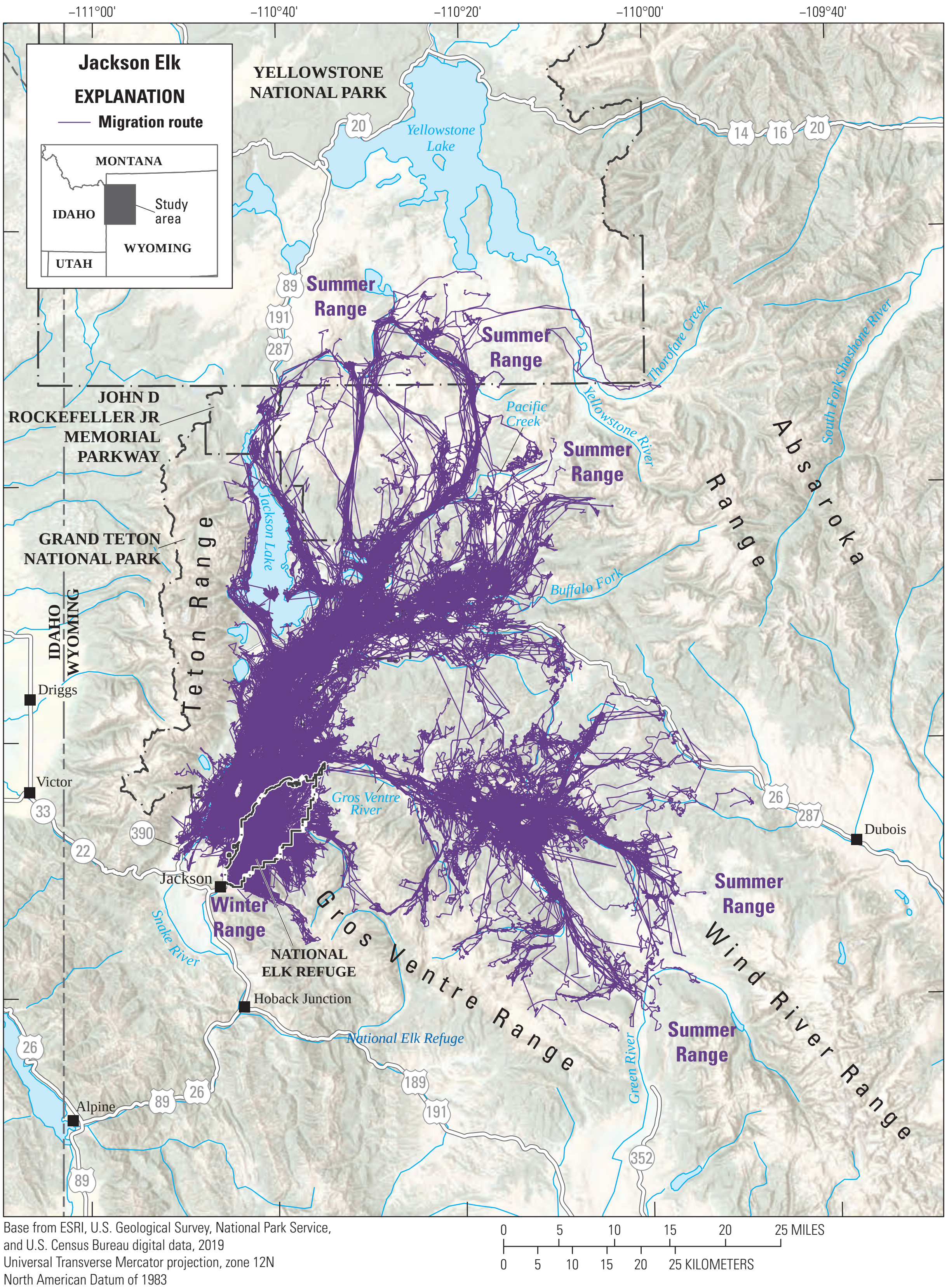


Figure 46. Migration routes of the Jackson elk herd.

Wyoming | Elk

Jackson Elk Migration Routes

Elk within the Jackson herd have been the focus of wildlife management for over a century. The herd, which numbers between 9,000–13,000, winters in Jackson (fig. 46). Most of the herd winters in the sagebrush basins and irrigated fields of the National Elk Refuge, with less than a quarter of the herd wintering in the Gros Ventre River drainage to the east. Migrating animals travel an average one-way distance of 39 mi (63 km), with some migrating as far as 168 mi (270 km). The herd is partially migratory, containing both migrant and residents. In spring, the migrant animals move north on either side of Jackson Lake into the eastern foothills of the Teton Range and into the upper drainages of the Snake River and the southern portion of Yellowstone National Park. A smaller segment migrates east up the Gros Ventre River drainage and its upper tributaries. A study by the National Elk Refuge documented a long-term reduction in the migratory segment of the herd between 1978 and 2012 (Cole and others, 2015). This trend is thought to be driven by declining calf recruitment of the migratory segment. Few obstacles to migration exist for this herd, which moves through a vast expanse of habitats managed by either the National Forest or National Park system.

Animal Capture and Data Collection

Sample size: 269 adult female elk
Relocation frequency: ~2 hours
Project duration: 2006–2018

Data Analysis

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

Models derived from:

- Migration: 595 sequences from 247 individuals (344 spring sequences, 251 fall sequences)
- Winter: 402 sequences from 261 individuals

Route Summary

Migration start and end date (median):

- Spring: April 25 to May 19
- Fall: November 1 to November 25

Days migrating (mean):

- Spring: 26 days
- Fall: 27 days

Migration route length:

- Min: 5 mi (8.0 km)
- Mean: 39 mi (62.8 km)
- Max: 168 mi (270.4 km)

Winter Use Summary

Winter use start and end date (median):

- January 5 to April 6

Days of winter use (mean): 77 days

Other Information

Project contacts:

- Alyson Courtemanch (alyson.courtemanch@wyo.gov), Regional Biologist, Wyoming Game and Fish Department
- Eric Cole (eric_cole@fws.gov), Wildlife Biologist, USFWS National Elk Refuge
- Sarah Dewey (sarah_dewey@nps.gov), Wildlife Biologist, Grand Teton National Park

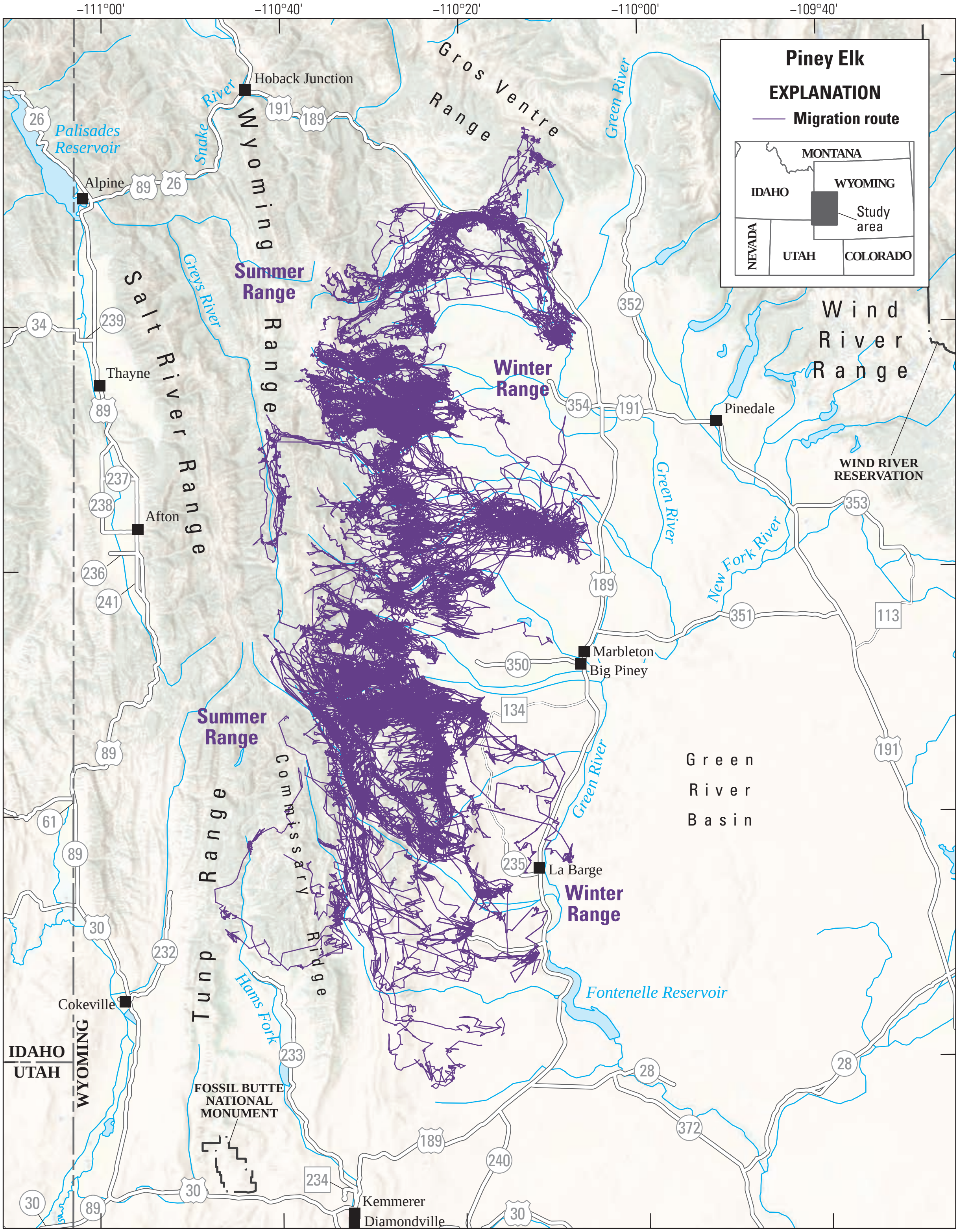
Data analyst:

- Matthew Cuzzocreo, Sr. Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming

Reports and publications:

- Cole, E.K., Foley, A.M., Warren, J.M., Smith, B.L., Dewey, S.R., Brimeyer, D.G., Fairbanks, W.S., Sawyer, H., and Cross, P.C., 2015, Changing migratory patterns in the Jackson elk herd: The Journal of Wildlife Management, v. 79, no. 6, p. 877–886. [Also available at https://doi.org/10.1002/jwmg.917.]

Photograph from Scott Copeland.



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

Figure 47. Migration routes of the Piney elk herd.

Wyoming | Elk

Piney Elk Migration Routes

Migratory movements of elk within the Piney herd unit—a large area encompassing the eastern side of the Wyoming Range—include short (in other words, 10 mi [16 km]) to medium (in other words, 30 mi [48 km]) distance migrations (fig. 47). These elk migrate from low-elevation elk feedgrounds and native winter ranges in the Upper Green River Basin to high elevation summer ranges in the Wyoming Range. Challenges for Piney elk include energy development, especially in the southern portion of the Piney herd unit.

Animal Capture and Data Collection

Sample size: 167 adult female elk
Relocation frequency: ~2 hours
Project duration: 1999–2001 and 2006–2019

Data Analysis

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

Models derived from:

- Migration: 306 sequences from 158 individuals (186 spring sequences, 120 fall sequences)
- Winter: 286 sequences from 166 individuals

Route Summary

Migration start and end date (median):

- Spring: April 17 to May 28
- Fall: November 5 to December 8

Days migrating (mean):

- Spring: 40 days
- Fall: 35 days

Migration route length:

- Min: 7 mi (11.2 km)
- Mean: 47 mi (75.6 km)
- Max: 164 mi (263.9 km)

Winter Use Summary

Winter use start and end date (median):

- January 5 to April 8

Days of winter use (mean): 88 days

Other Information

Project contacts:

- Brandon Scurlock (brandon.scurlock@wyo.gov), Wildlife Management Coordinator, Wyoming Game and Fish Department

Data analyst:

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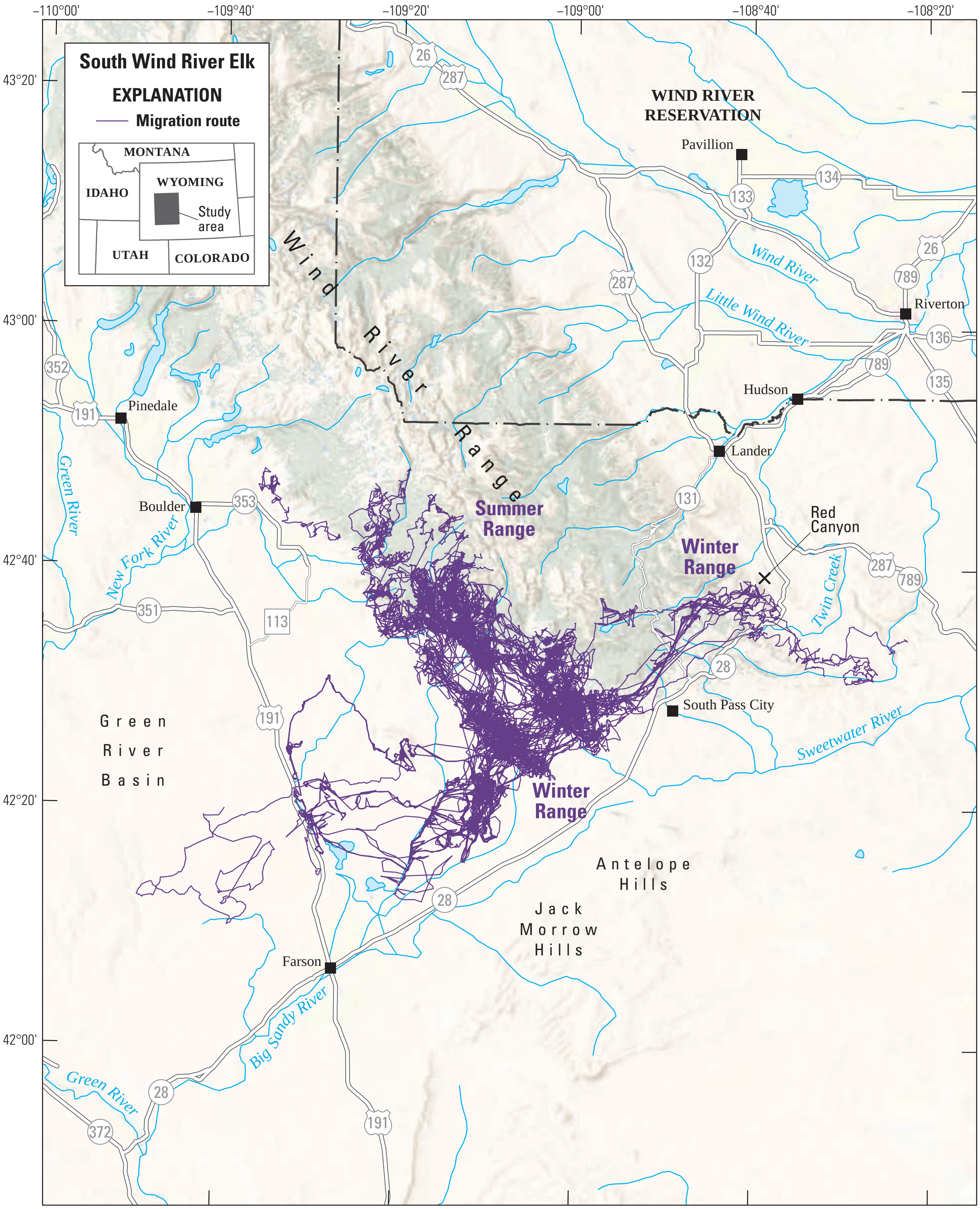
- Julien Fattebert, Post Doctoral Researcher, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming

Photograph from Brandon Scurlock, 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 12N
North American Datum of 1983

0 5 10 15 20 25 MILES
0 5 10 15 20 25 KILOMETERS

Figure 48. Migration routes of the South Wind River elk herd.

Wyoming | Elk

South Wind River Elk Migration Routes

Migratory movements of elk within the South Wind River herd include short (in other words, 10 mi [16 km]) to medium (in other words, 40 mi [64 km]) distance migrations generally from low elevation winter ranges along the foothills to high elevation summer ranges within the Wind River Range (fig. 48). Elk movements along the west side of the Wind River Range trend southwesterly from summer ranges to winter ranges, largely dependent upon winter severity. Some individuals traverse the Wind River Range and winter in Red Canyon. There are a number of challenges for South Wind River elk. These include increasing vehicle collisions on U.S. Highways 287 and 789 from Twin Creek to South Pass City and potential future energy development along the western side of the Wind River Range where recent oil and gas leasing has occurred on lands managed by the Bureau of Land Management and the State of Wyoming.

Animal Capture and Data Collection

Sample size: 24 adult female elk
Relocation frequency: ~2 hours
Project duration: 2008–2014

Data Analysis

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

Models derived from:

- Migration: 60 sequences from 24 individuals (30 spring sequences, 30 fall sequences)
- Winter: 21 sequences from 17 individuals

Route Summary

Migration start and end date (median):

- Spring: April 23 to June 23
- Fall: November 4 to December 10

Days migrating (mean):

- Spring: 51 days
- Fall: 42 days

Migration route length:

- Min: 14 mi (22.5 km)
- Mean: 56 mi (90.1 km)
- Max: 116 mi (186.7 km)

Winter Use Summary

Winter use start and end date (median):

- January 27 to March 18

Days of winter use (mean): 56 days

Other Information

Project contacts:

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Data analyst:

- Matthew Cuzzocreo, Sr. Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming

Photograph from Gregory Nickerson.

Moose

As the second-largest mammal in North America, moose still occupy much of their historic range throughout Canada, Alaska, and some mainland U.S. states close to the Canadian border (fig. 49). The word “moose” originates from an Algonquin term, “moosh,” meaning, “stripper and eater of bark” Throughout the U.S. Rocky Mountains, moose are considered relatively recent immigrants. They dispersed from northern Idaho and northwestern Montana during the mid-1800s to colonize areas of southern Idaho, Wyoming, and Utah. Wildlife officials in Colorado have reintroduced moose in four areas of the state since 1978.

Moose are browsing ruminants that typically occupy riparian habitat and adjacent forested areas. As a generalist browser, moose have specific salivary proteins that aid digestion of up to 40 lb (18 kg) of forage a day (Randel, 2009). They primarily forage on shrubs, young trees, and forbs. Moose are often observed feeding in habitat recently disturbed from fire or logging (in other words, 2–26 years post-fire), as forest regeneration stimulates the production of palatable and digestible plants (Nelson and others, 2008). Moose also forage in lakes and ponds to access mineral-rich aquatic plants, such as *Nymphaea* spp. (water lilies) and *Potamogeton* spp. (pondweed). Moose are excellent swimmers and can dive up to 20 ft underwater (de Vos, 1958). Once submerged, they use their long nasal passage to blow away mud burying aquatic plants they want to eat. During winter, moose shift their diets to the woody stems of *Salix* spp. (willow), *Populus tremuloides* (aspen), *Populus* spp.(cottonwood), and *Abies* spp. (fir). In some areas of the western United States (for example, Utah and Wyoming), moose will forage in open areas containing *Purshia tridentate* (antelope bitterbrush), *Quercus* spp. (oak), and *Prunus virginiana* (chokecherry).

Throughout the western United States, moose migratory behavior ranges from entirely resident with overlapping summer and winter ranges (for example, in northern Idaho), to largely migratory (for example, Jackson population in northwest Wyoming). During spring and fall, migratory individuals will travel relatively short distances (5–30 mi [8–48 km]) along drainages to their corresponding seasonal range (Becker, 2008; Vartanian, 2011; Oates, 2016). Their large body size, long legs, and splaying hooves—combined with their dietary niche—allow moose to survive harsh winter environments along a broad elevation range that deters most ungulate species. Consequently, moose can be facultative migrants, choosing whether to migrate relative to weather conditions, food availability, and vulnerability to predation.

Moose are sensitive to parasites and disease, especially during warm years (Samuel, 2007). Winter ticks can aggregate by the thousands on a single moose, decreasing nutritional condition over winter through the loss of blood. Henningsen and others (2012) documented the presence of a nematode parasite, *Elaeophora schneideri*, which is transmitted by horse flies and appears to have been at high prevalence near the Greater Yellowstone Ecosystem. Chronic wasting disease in moose has also been detected in western Wyoming, northwest Montana, and Colorado. Despite their impressive size and defensive capabilities, moose are also prey for a suite of large carnivores. Grizzly bears and, to a lesser extent, black bears, will prey on young moose calves during early summer (Ballard and Miller, 1990; Gasaway and others, 1992), and wolves (Peterson, 1977) and cougars (Ross and Jalkotzy, 1996) will prey on all age classes year round.

Moose populations throughout the lower 48 states are thought to be in decline, due to a combination of interacting factors such as parasites, disease, predators, habitat change, and warming temperatures (DeCesare and others, 2014; Timmermann and Rodgers, 2017). Relative to elk and deer, moose are much less common throughout the Rocky Mountains. Nadeau and others (2017) reported that population estimates of moose were 2,400 in Colorado; 10,000 in Idaho; 4,000 in Montana; 20 in Nevada; 70 in Oregon; 2,625 in Utah; 5,169 in Washington; and 4,650 in Wyoming.

In this report, select moose migrations have been mapped for Wyoming. The mapping of routes follows a standard procedure. Details are given in the summary statistics associated with each map. Analytical methods are provided in Appendix 1. For Wyoming herds, moose corridors have not been officially designated by the state, and thus only the routes (in other words, lines) are shown in the associated maps.

Figure 49. Current range of moose in North America (Demarais and Krausman, 2000).

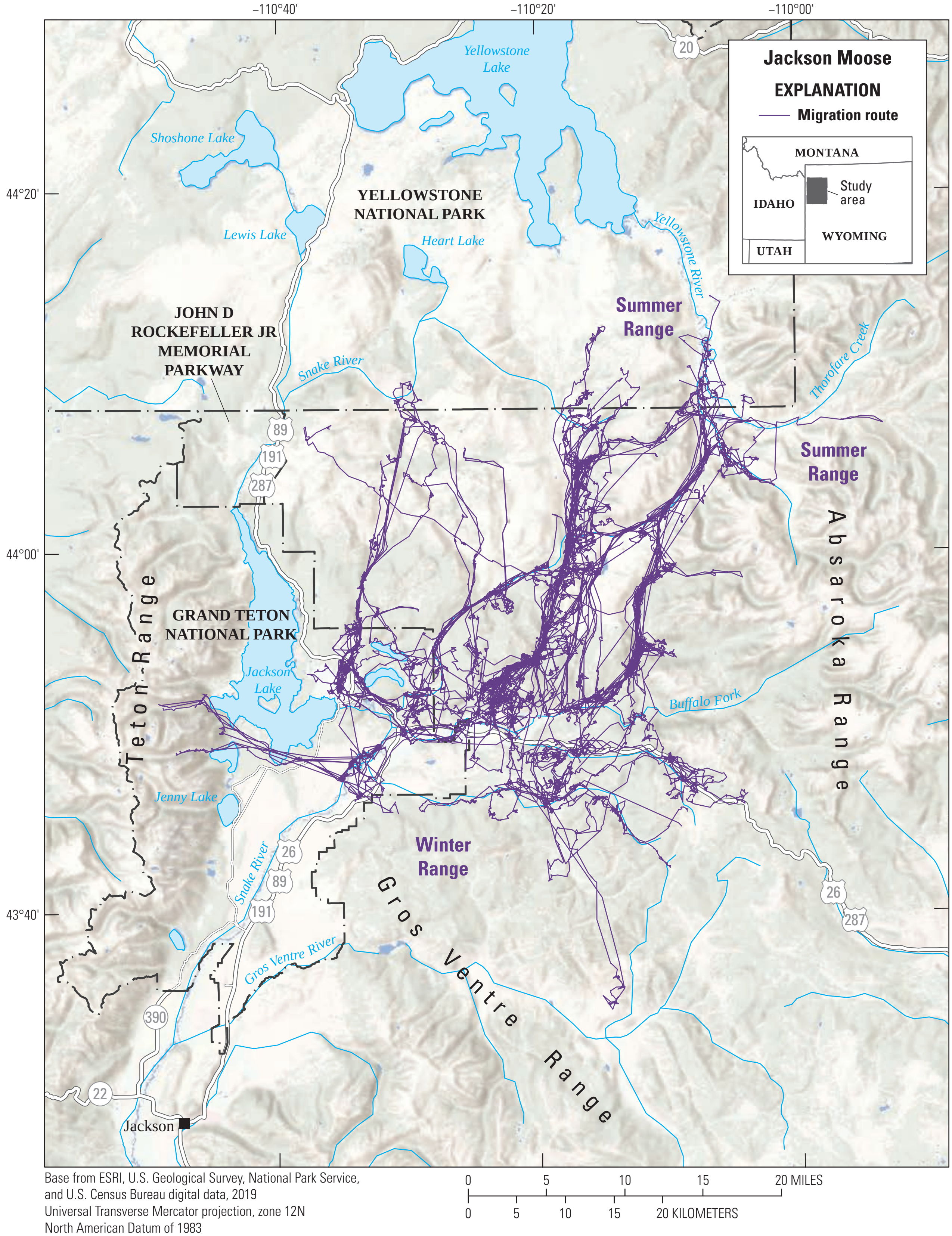

Figure 50. Migration routes of the Jackson moose herd.

Wyoming | Moose

Jackson Moose Migration Routes

Moose in the Jackson herd make an elevational migration in the southern portion of the Greater Yellowstone Ecosystem (fig. 50). This small herd of approximately 500 animals winters primarily in the Buffalo Valley just east of Jackson Lake. During migration, animals travel an average one-way distance of 33 mi (53 km), with some animals migrating as far as 67 mi (108 km). In the spring, most moose migrate north into the Teton Wilderness or the southern extent of Yellowstone National Park. Summer ranges consist of a mix of conifers and riparian habitats along the upper watersheds that flow into the Snake River. Nearly all moose in this herd are migratory, with the herd sharing a common winter range then branching out in the spring to summer ranges to the north and west. Over the last decade or so, Jackson moose have experienced poor recruitment due to lingering effects of the 1988 fires, prolonged drought, and increased rates of predation by grizzly bears and wolves, although recruitment rates have been improving over the last 5 years or so. Despite the poor demographic performance, the migrations are relatively intact because most routes overlap public lands.

Animal Capture and Data Collection

Sample size: 41 adult female moose
Relocation frequency: ~1 hour
Project duration: 2005–2010

Data Analysis

Delineation of migration periods: Net Squared Displacement (Bunnefeld and others 2011)
Models derived from:

- Migration: 94 sequences from 33 individuals (47 spring sequences, 47 fall sequences)
- Winter: 86 sequences from 41 individuals

Route Summary

Migration start and end date (median):

- Spring: May 11 to June 6
- Fall: November 7 to December 6

Days migrating (mean):

- Spring: 32 days
- Fall: 25 days

Migration route length:

- Min: 4.1 mi (6.6 km)
- Mean: 25.2 mi (40.6 km)
- Max: 68.5 mi (110.2 km)

Winter Use Summary

Winter use start and end date (median):

- January 1 to March 18

Days of winter use (mean): 61 days

Other Information

Project contacts:

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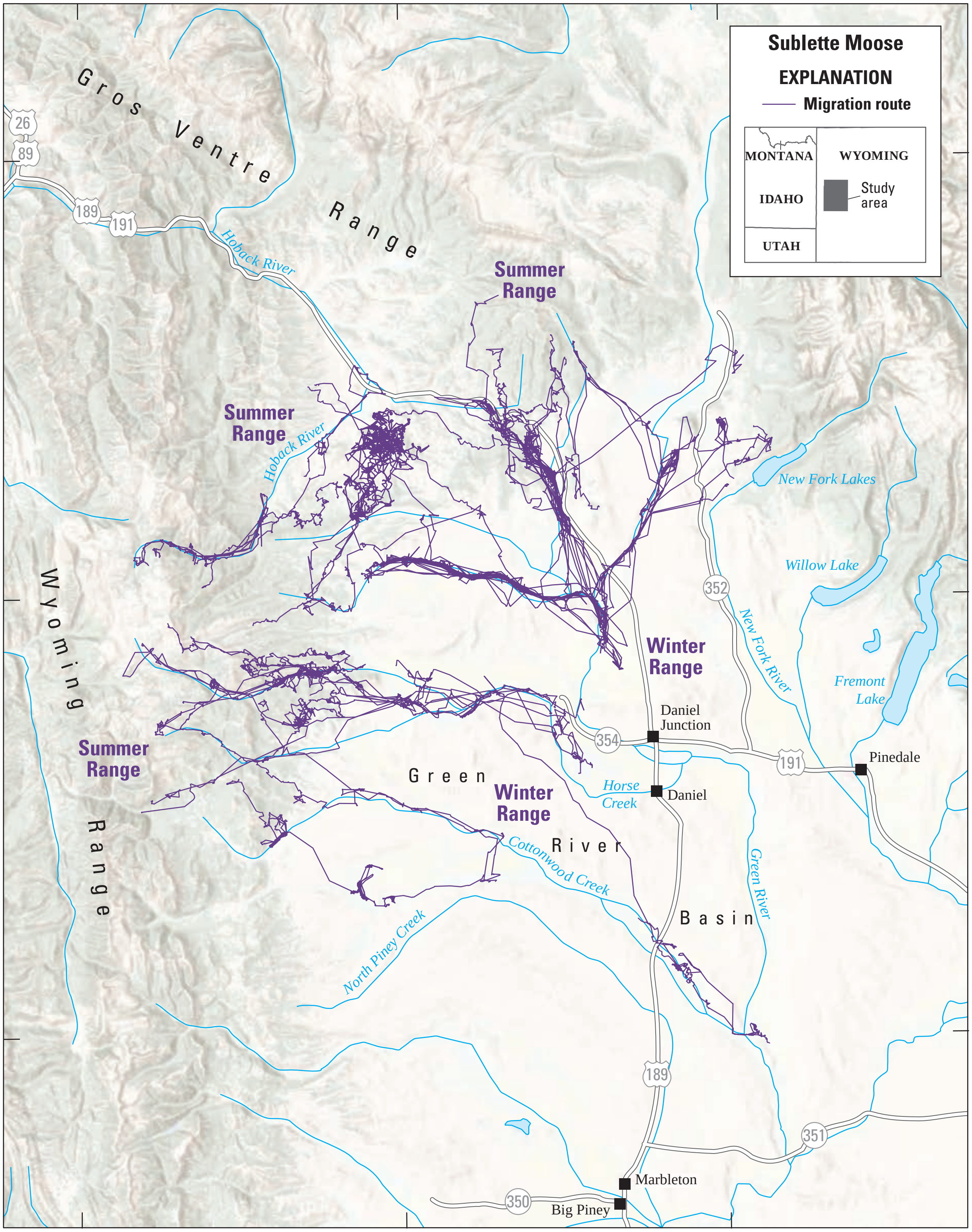
Data analyst:

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

Reports and publications:

- Oates, B.A., Merkle, J.A., Kauffman, M.J., Dewey, S.R., Jimenez, M.D., Vartanian, J.M., Becker, S.A., and Goheen, J.R., 2019, Antipredator response diminishes during periods of resource deficit for a large herbivore: Ecology, v. 100, no. 4. [Also available at https://doi.org/10.1002/ecy.2618.]


Photograph from Andrew Slapton.



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 2 4 6 8 10 12 14 MILES
0 2 4 6 8 10 12 14 KILOMETERS

Figure 51. Migration routes of the Sublette moose herd.

Wyoming | Moose

Sublette Moose Migration Routes

The Sublette herd is the largest moose population in Wyoming, numbering approximately 1,800 individuals (fig. 51). This herd winters among the willow-dominated flood plains of the Green River Basin, primarily in the eastern foothills of the Wyoming Range; some animals winter also in the Hoback Basin. As a partially migratory population, approximately half of the moose are resident, while migratory individuals travel short distances (14 mi [23 km] on average, with a maximum of 45 mi [72 km]) primarily to tributaries of the Green and Hoback Rivers. During spring, most migration routes originate on private ranchlands within the expansive willow bottoms of Horse, Cottonwood, and North Piney Creeks, as well as the aspen-conifer forests along the Hoback River. Migratory individuals typically travel upstream, within or near the same drainage that they wintered. During migration, moose encounter many fences, low-use county roads, and some must cross Highway 191 to reach their summer ranges. Migratory moose often arrive on summer ranges within the Bridger-Teton National Forest along the front of the Wyoming Range. Most summer ranges used by moose on the National Forest were withdrawn from oil and gas development due to the Wyoming Range Legacy Act passed by the U.S. Congress in 2009.

Animal Capture and Data Collection

Sample size: 54 adult female moose
Relocation frequency: ~1 hour
Project duration: 2011–2014

Data Analysis

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

Models derived from:

- Migration: 91 sequences from 41 individuals (54 spring sequences, 37 fall sequences)
- Winter: 42 sequences from 41 individuals

Route Summary

Migration start and end date (median):

- Spring: April 4 to April 24
- Fall: November 28 to Decemeber 13

Days migrating (mean):

- Spring: 36 days
- Fall: 25 days

Migration route length:

- Min: 3.7 mi (6.0 km)
- Mean: 14.4 mi (23.2 km)
- Max: 45.7 mi (73.5 km)

Winter Use Summary

Winter use start and end date (median):

- January 15 to March 2

Days of winter use (mean): 39 days

Other Information

Project contacts:

- Brandon Scurlock (brandon.scurlock@wyo.gov), Wildlife Management Coordinator, Wyoming Game and Fish Department
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Data analyst:

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Photograph from Mark Gocke, Wyoming Game and Fish Department.

Bison

Bison (*Bison bison*) are the largest terrestrial mammal in North America. Males can weigh 2,000 lbs [907 kg], reaching nearly double the size of females. Plains bison once encompassed the largest area of any large herbivore native to North America, as 30–50 million once ranged more than 350,000,000 mi^2. Just 200 years ago, bison moved across the Great Plains and montane grasslands in vast herds of up to 10,000 individuals, serving as a major ecological keystone species (Wildlife Conservation Society, 2007). A continent-wide survey conducted in 2002 found that of the approximately 500,000 plains bison in North America, only 20,000 are managed for conservation purposes and these 'conservation' herds are confined to small geographically isolated herds that are heavily managed to maintain population size (fig. 52).

When good forage is available, bison prefer highly nutritious sedges and grasses. Such forage may be available in some ecosystems or become occasionally available through regeneration after fire and during spring green-up. By continuously foraging, urinating, defecating, and removing older, dead plants in an area, they essentially cultivate their own 'grazing' lawns of high-quality grasses (McNaughton, 1984; Geremia and others, 2019). Like other ungulate species, migratory bison follow the wave of emerging green forage that moves up in elevation as spring progresses, snow melts, and temperatures warm. They then move back to low elevations when snow accumulates in the mountains in late winter. These behaviors are limited, however, by the area that most bison are allowed to occupy in the modern era. Thus, many bison, both wild and in captivity, have become bulk feeders which spend 9–11 hours each day eating large amounts of weeds and low-quality grasses.

Currently, intense land management constrains most bison herds to relatively small, fenced-in areas, restricting natural migratory behavior. Some exceptions include the free-roaming Henry Mountains herd in Utah and the Wind Cave herd in South Dakota. There are also several free-roaming herds in Canada, including Prince Albert National Park (Saskatchewan), Wood Buffalo National Park (Alberta and Northwest Territories), and Banff and Elk Island National Parks (Alberta). The most iconic free-roaming bison are the 5,000 animals that reside mostly within Yellowstone National Park. Over the last century, individuals in this population have learned to migrate up to 80 mi (97 km) (Geremia and others, 2019) and can now be considered the last truly migratory herd. The migratory movements of Yellowstone bison are also truncated, however. They are not allowed to move freely outside the park for concerns about human safety, disease transmission, conflicts with domestic livestock, and protection of property (National Park Service, 2020).

By the end of the 19th century, overhunting had virtually eliminated bison; by 1900, only a few hundred individuals remained. Although bison numbers are generally increasing, with more than half a million alive today, the number of bison in herds that still serve a functional role in ecosystems has not changed for decades. Many biologists (including geneticists) agree that bison herds should be large (thousands of individuals), allowed to move more than thousands of square kilometers, and be exposed to natural predators such as wolves, in order to serve their ecological role on the landscape. However, only a small fraction of the bison alive today reside in these ecologically relevant herds (Sanderson and others, 2008).

In this report, bison corridors, stopovers, and winter range have been mapped for the population that occupies Yellowstone National Park. The mapping of these data follows a standard procedure, as described by Sawyer and others (2009b). Details are given in the summary statistics associated with each map, with analytical methods provided in Appendix 1.

Figure 52. Conservation herd locations and historic range of bison in North America (Demarais and Krausman, 2000).

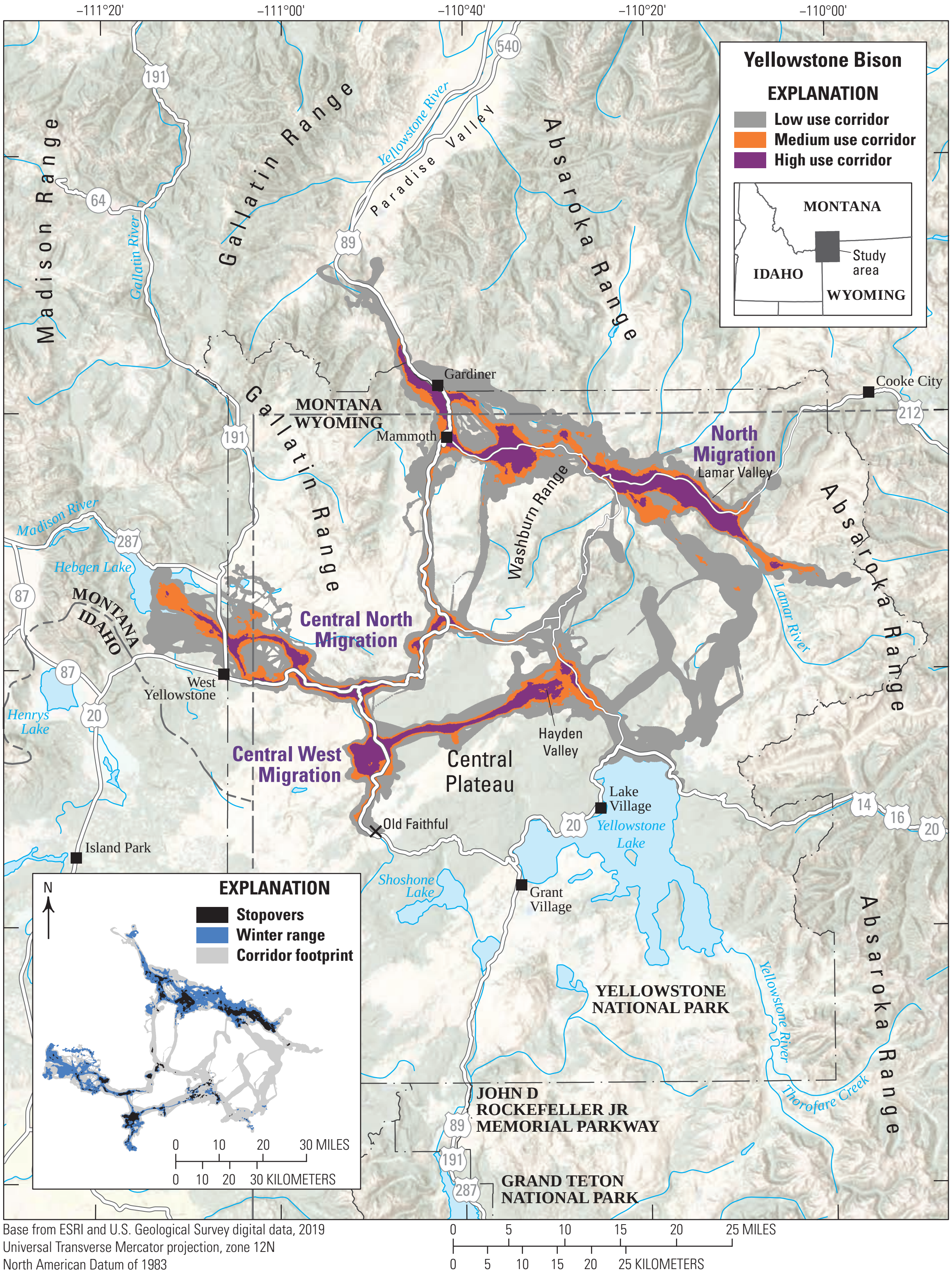

Figure 53. Migration corridors, stopovers and winter range of the Yellowstone bison herd.

Yellowstone | Bison

Plains bison in Yellowstone National Park represent one of the last ecologically relevant populations in North America. Although bison are mainly confined to park boundaries, individuals migrate up to 80 mi (129 km) from lower elevations just outside the park to higher elevations in the central part of the park (fig. 53). There are three major bison migration routes within Yellowstone National Park: North, Central-West, and Central-North. Bison do not preemptively migrate to avoid deep snow in autumn. Instead they "play the winter," pushing a bit farther down the valleys with each snowstorm and sometimes lingering between summer and winter range for weeks or even months. Most Yellowstone bison have two migration routes: one they use in light winters, and an extended version they use during heavy winters. If snow remains thin, they stay close to their summer ranges deep inside Yellowstone. When snow piles up, bison head down river, moving to and beyond the park boundaries. While multiagency efforts are being made to accommodate these migrations, bison are still restricted to Yellowstone National Park and limited to areas just outside the park. Outside the park, bison are permitted on a small region near Gardiner and West Yellowstone, Montana, as well as near east entrance, near Cody, Wyo.

Animal Capture and Data Collection

Sample size: 92 female bison
Relocation frequency: ~1 hour
Project duration: 2004–2017

Data Analysis

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

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

Models derived from:

- Migration: 159 sequences from 92 individuals (55 spring sequences, 104 fall sequences)
- Winter: 254 sequences from 95 individuals

Corridor and Stopover Summary

Migration start and end date (median):

- Spring: April 12 to June 20
- Fall: February 19 to April 5

Days migrating (mean):

- Spring: 63 days
- Fall: 42 days

Migration corridor length:

- Min: 21 mi (33.8 km)
- Mean: 57 mi (91.7 km)
- Max: 81 mi (130.4 km)

Migration corridor area:

- 392,762 acres (158,945.1 ha) (low use)
- 120,420 acres (48,732.2 ha) (medium use)
- 57,331 acres (23,201.0 ha) (high use)

Stopover area: 39,882 acres (16,139.7 ha)

Winter Range Summary

Winter start and end date (median):

- March 27 to April 20

Days of winter use (mean): 28 days
Core winter range (50 percent contour) area: 149,397 acres

Other Information

Project contacts:

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Data analyst:

- Jerod Merkle, Assistant Professor, University of Wyoming

Reports and publications:

- Geremia, C., White, P.J., Wallen, R.L., Watson, F.G.R., Treanor, J.J., Borkowski, J., Potter, C.S., and Crabtree, R.L., 2011, Predicting bison migration out of Yellowstone National Park using Bayesian models: PLoS One, v. 6, no. 2. [Also available at https://doi.org/10.1371/journal.pone.0016848.]
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Photograph from Neal Herbert, National Park Service.

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Publishing support provided by the Science Publishing Network, Denver Publishing Service Center

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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, 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 GPS location of an animal's movement trajectory and a point within the animal's winter range. When an animal stays within a defined home range, the NSD varies relatively little over time as the animal travels. 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 within each given migration sequence.

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 the probability of where the animal could have traveled during its migration (in other words, utilization distribution, hereafter, UD). The UD provides a heat map (representing probability) of use for each migration sequence. Thus, the UD estimates the width of the movement path around the straight line between two successive locations and can therefore be used to identify migration corridors (Sawyer and others, 2009b) and the stopover sites where animals spent extended time foraging along their movement path (Sawyer and Kauffman, 2011).

Using a grid with 50-m (164-ft) resolution, we calculated a BBMM for each migration sequence. 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 following the methods of Horne and others (2007) from the location data used to construct each BBMM. Thus, a unique BMV was estimated for each migration sequence. In most cases, we did not include migration sequences with a BMV ≥ 8,000 unless visual inspection of the corridors or low sample size justified inclusion (Idaho, however chose not to use this threshold).

Variations of the Method—Sparse Data and Fixed Motion Variance

When location data are sparse (in other words, when GPS fixes are not taken very often), BBMM performs poorly. In these cases, there is a higher uncertainty of the animal's movement path between successive GPS fixes (Horne and others, 2007; Benhamou, 2011). Fitting a BBMM to sparse empirical data inflates the estimate of the BMV, which leads to overestimates of the corridor width and area. This limits the application of BBMM modeling for corridor delineation to datasets with fix rates less than every 3 to 5 hours. Yet, many datasets on ungulate movements are collected using "life cycle" collars that log a GPS fix every 13 hours.

To facilitate corridor analyses of migration sequences collected with life-cycle collars, we developed a modification of the traditional BBMM approach. Instead of estimating the BMV empirically for each migration sequence as discussed above, we provided the BBMM code with a fixed value of motion variance (Fixed Motion Variance, hereafter, FMV) for all migration sequences in a given population. Our FMV method, discussed in detail in the subsequent paragraph, provided estimates of corridor area that were comparable to using typical 2-hour GPS collar fix rates.

To estimate biologically meaningful FMV values for elk and mule deer, we tested a range of values against those generated from the standard 2-hour BBMM approach described above. For our analysis, we identified three mule deer herds and three elk herds with GPS locations at 2-hour intervals, subsetting the datasets to 1 fix every 12 hours as a proxy for life-cycle collar data. We calculated individual probability of use as well as population-level migration corridors on the original 2-hour data as a baseline "truth" (see above) and calculated individual probability of use and population-level migration corridors on the thinned data using different values of the FMV ranging from 200 to 3,000. The "baseline corridor" was defined as the corridor calculated with 2-hour data and the "sparse corridor" as the corridor calculated with 12-hour data for each value of the FMV. We first calculated the proportion (percent overlap) of the baseline corridor overlapped by the sparse corridor and then defined relative area as the ratio of the area of the sparse corridor with the area of the baseline corridor. Finally, the FMV value that maximized the percent overlap while minimizing the relative area was selected for each level of the corridor (low, medium, high, and stopover; fig. 1.2).

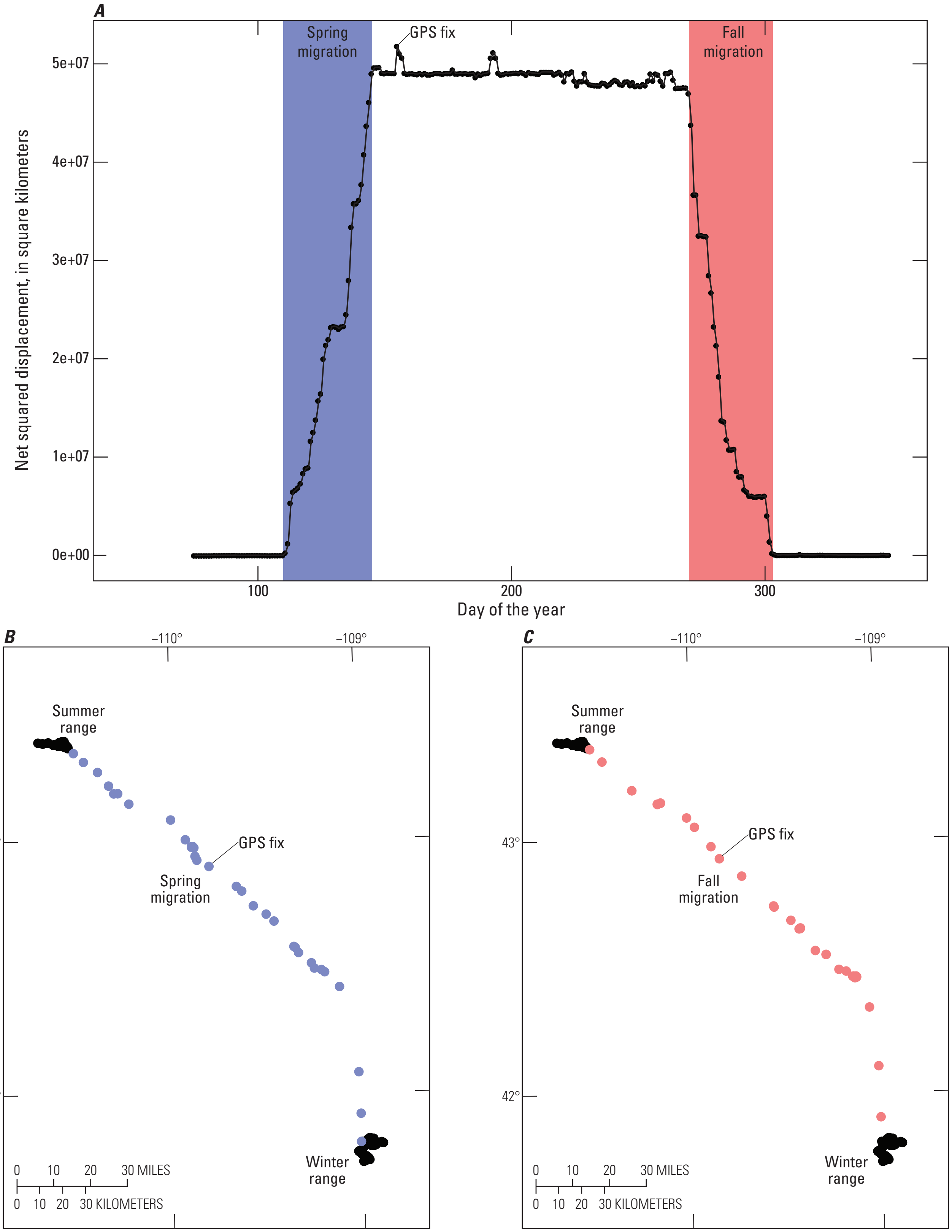

Figure 1.1. Example of Net Squared Displacement (NSD) analysis to identify migration sequences. Breakpoints in the NSD curve provide the start and end dates for the spring migration (blue polygon) when an animal migrates away from winter range to summer range. Fall migration (red polygon) is shown when 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.

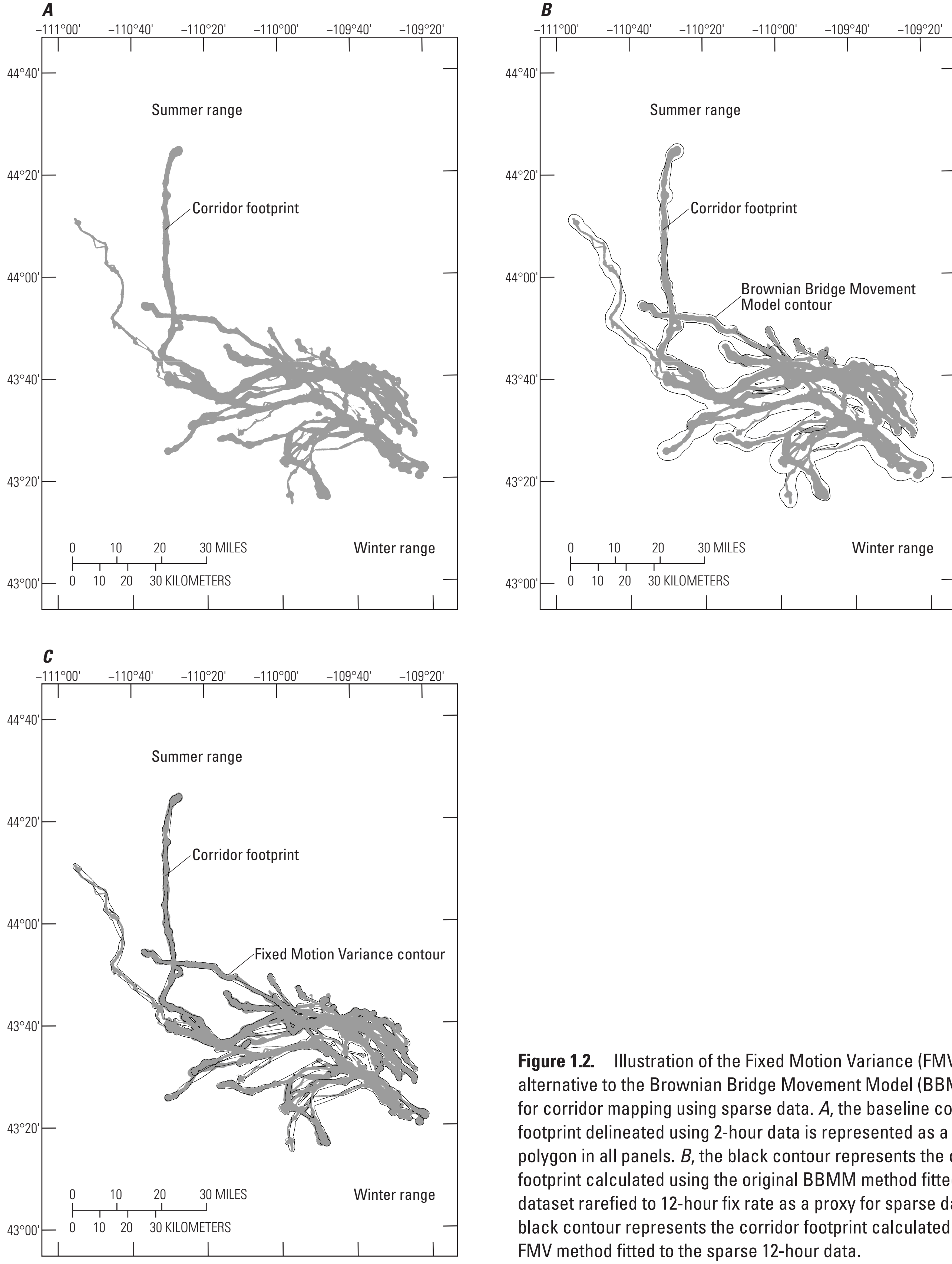

Figure 1.2. Illustration of the Fixed Motion Variance (FMV) alternative to the Brownian Bridge Movement Model (BBMM) for corridor mapping using sparse data. *A*, the baseline corridor footprint delineated using 2-hour data is represented as a gray polygon in all panels. *B*, the black contour represents the corridor footprint calculated using the original BBMM method fitted to the dataset rarefied to 12-hour fix rate as a proxy for sparse data. *C*, the black contour represents the corridor footprint calculated using the FMV method fitted to the sparse 12-hour data.

We found that FMV values of 1,400 for elk and 1,000 for mule deer, while specifying a maximum time lag of 1 fix interval plus 1 hour, provided corridors that most closely resembled those calculated using 2-hr data. A smaller FMV value would generate a tighter corridor, while a larger maximum time lag of 2 fix intervals plus 1 hour allows building Brownian bridges between successive locations farther apart in time, in other words, allowing one for missing GPS fix.

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 approach outlined by Sawyer and others (2009b). 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. Then, we defined a migration footprint for each individual as the 99 percent isopleth of this UD and stacked up all the individual footprints for a given population and defined different levels of corridor use based on the number of individuals using a given pixel. Low-use corridors were defined as areas traversed by ≥1 individual during migration, medium-use corridors were used by ≥10 percent of individuals within the population, and high-use corridors were used by ≥20 percent 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 m^2 (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 top 10 percent of the area of use from the population-averaged UD values. As with the corridors, we then converted stopovers from a grid-based format to a polygon format and then removed isolated polygons of less than 5 acres.

Variations of the Method to Calculate Population-Level Corridors

Most maps in this report display low-, medium- and high-use corridors or routes. In general, low-use included one animal, medium use = 10–20 percent and high use = ≥ 20 percent of the collared sample. Typical breakpoints between low, medium, and high categories were explained above; however, some individual states adapted methologies that best suited their management purposes. For example, in Idaho, low-use was defined as 2 individuals ranging up to 10 percent, and when sample size was ≤ 30 individuals, only medium- and high-use corridors were shown. Also, in Wyoming, only corridors are shown that are officially designated by the Wyoming Game and Fish Department; these corridors represent areas where ≥ 2 individuals migrate.

In the vast majority of cases, traditional BBMM methods were used to calculate corridors and stopovers. However, when there were significant amounts of data-acquisition failures in the migration sequences due to topography, corridors were calculated using FMV techniques if they improved delineation. In general, by bridging gaps in the probability surface due to missing GPS locations, using FMV provided a modeled corridor that more closely matches 2-hr data. In most of these cases, a 14-hr time lag was used. A 27-hr time lag was used only when it provided more complete migration corridors compared to using a 14-hour time lag. In Idaho and Arizona, when FMV was employed to calculate corridors, a FMV value of 1000 was used for mule deer and 1,400 was used for elk. In Idaho, if the annual or multi-annual footprints of an individual animal did not include 50 percent of the individual's seasonal migration route identified by the GPS points, then that individual was dropped from the analysis. When converting final corridors from grid to polygon data, all 50-m pixels were preserved in the final migration corridors and stopovers.

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 are 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, Dec.15–Mar. 15). We discarded winter sequences that spanned less than 30 days. Following the methods for migration corridors, we calculated a population-level UD of winter use and identified the core winter range using the 50th percent isopleth (Nevada core winter range isopleth equals 30 percent).

Kauffman and others—**Ungulate Migrations of the Western United States, Volume 1**—Scientific Investigations Report 2020–5101, ver. 1.1

ISBN 978-1-4113-4379-5

ISSN 2328-031X (print)
ISSN 2328-0328 (online)
https://doi.org/10.3133/sir20205101

Printed on recycled paper