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Ungulate Migrations of the Western United States, Volume 4

Scientific Investigations Report 2024–5006

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

Cover. Elk from the Cody herd migrate over Needle Mountain (12,111 feet [3,691 meters]) in Park County, Wyoming. The herd's summer range is on the Thorofare Plateau of Yellowstone National Park, whereas the winter range is split between the Shoshone National Forest and private lands along the eastern slope of the Absaroka Range. (Photograph from Joe Riis, used with permission)

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By Matthew Kauffman, Blake Lowrey, Chloe Beaupre, Scott Bergen, Stefanie Bergh, Kevin Blecha, Samantha Bundick, Hunter Burkett, James W. Cain III, Peyton Carl, David Casady, Corey Class, Alyson Courtemanch, Michelle Cowardin, Jennifer Diamond, Katie Dugger, Orrin Duvuvuei, Joanna R. Ennis, Michelle Flenner, Jessica Fort, Gary Fralick, Ian Freeman, Jeff Gagnon, David Garcelon, Kyle Garrison, Emily Gelzer, Evan Greenspan, Valerie Hinojoza-Rood, Pat Hnilicka, Andy Holland, Brian Hudgens, Bart Kroger, Art Lawson, Cody McKee, Jennifer L. McKee, Jerod Merkle, Tony W. Mong, Haley Nelson, Brendan Oates, Marie-Pier Poulin, Craig Reddell, Robert Ritson, Hall Sawyer, Cody Schroeder, Jessie Shapiro, Scott Sprague, Erik Steiner, Alethea Steingisser, Sam Stephens, Blair Stringham, Patrick Ryan Swazo-Hinds, Nicole Tatman, Cody F. Wallace, Don Whittaker, Benjamin Wise, Heiko U. Wittmer, and Erin Wood

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Contents

Sidebar

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Plate

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
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)
	Power	
megawatt (MW)	1×10^6	joules per second (J/s)
gigawatt (GW)	1×10^9	joules per second (J/s)

Datum

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

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

Abbreviations

<	less than
>	greater than
AADT	average annual daily traffic
BBMM	Brownian bridge movement model
BLM	Bureau of Land Management
BMV	Brownian motion variance
CMT	Corridor Mapping Team
CWD	chronic wasting disease
DNA	deoxyribonucleic acid
FS	U.S. Department of Agriculture Forest Service
GPS	global positioning system
GYE	Greater Yellowstone Ecosystem
HMA	Herd Management Area
NSD	Net Squared Displacement
ODFW	Oregon Department of Fish and Wildlife
UD	utilization distribution
USGS	U.S. Geological Survey
WMU	Wildlife Management Unit
WVC	wildlife-vehicle collisions

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Abstract

Broadly distributed across the Western United States, ungulates (hooved mammals) play an important role in ecosystem function by affecting vegetation communities and forming the prey base for large carnivores. Additionally, ungulates provide economic benefits to regional communities through tourism and hunting and hold cultural significance for many Tribal communities. Many ungulates migrate seasonally between distinct summer and winter ranges to take advantage of spatially and temporally variable food sources and avoid threats such as predators and deep snow. Increasingly, these migrations are threatened by the growing human footprint and associated subdivisions, energy development, and increased traffic volume. Efforts to study ungulate populations and conserve their migrations received support in recent years from the U.S. Department of the Interior Secretarial Order No. 3362, which provided Federal support for enhancing habitat quality for ungulates across the Western States. In response to Secretarial Order No. 3362, the U.S. Geological Survey (USGS) established the Corridor Mapping Team, a collaboration among USGS and participating State and Federal wildlife management agencies and numerous Tribal Nations. Together, the Corridor Mapping Team maps ungulate migrations throughout the Western United States in the USGS "Ungulate Migrations of the Western United States" report series. This report (volume 4) details migrations and seasonal ranges from 31 new herds throughout nine Western States. Additionally, this report includes updates to two herds published in previous reports. Including this report, the report series has provided the mapped

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[13]New Mexico Department of Game and Fish.

[14]Navajo Nation Department of Fish and Wildlife.

[15]Arizona Game and Fish Department.

[16]Institute for Wildlife Studies.

[17]U.S. Fish and Wildlife Service.

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migrations and seasonal ranges of 182 unique herds and has provided a map-based inventory of the documented ungulate migrations across the Western United States for biologists, managers, policy makers, and conservation practitioners. This report also discusses how the mapping efforts associated with the Corridor Mapping Team can be used to guide management and policy regarding renewable energy development and ungulate disease, specifically chronic wasting disease, in the Western United States.

Introduction

Throughout their broad distribution in the Western United States, ungulates (hooved mammals) play an important role in ecosystem function by affecting vegetation communities (Hobbs, 1996; Frank and Evans, 1997) and forming the prey base for large carnivores. Additionally, ungulates provide economic benefits to regional communities through tourism and hunting (Duffield and Holliman, 1988) and hold cultural significance for many Tribal communities. Throughout the Western United States, many ungulates use seasonal migrations to avoid predators and deep snow, and to take advantage of spatially and temporally variable food sources (Kauffman and others, 2021a). Global positioning system (GPS) collars help identify and describe numerous ungulate migrations throughout the vast and rugged landscapes of the Western United States (Kauffman and others, 2020a, 2022a, c). These detailed movement data have facilitated research on the ecological drivers and benefits that underpin migrations across taxa. Collectively, these efforts helped identify migration as a critical behavior enabling ungulates to persist in the varied landscapes that compose much of the Western United States.

Congruous with the increased understanding of ungulate migration in recent decades, the Western United States has undergone widespread infrastructure development. The expanding human footprint in the Western States increasingly makes the migratory journeys of ungulates more difficult, threatening the long-term persistence of existing migrations (Sawyer and others, 2013). Roads, especially those roads with increasing traffic volumes, create significant barriers to ungulate movement, causing direct mortality and severing migrations (Kauffman and others, 2018; Robb and others, 2022). Additionally, increasing human recreational activities on State and Federal lands throughout the Western States can decrease habitat quality and displace ungulates from high-quality areas, effectively causing habitat loss. Human activities also lead to the expansion of *Juniperus* spp. (juniper) woodlands into previously *Artemisia* spp. (sagebrush)-dominated areas, suppressing fire and reducing fuel load, which may affect ungulate movements (Morano and others, 2019). Common on Western landscapes, fences also alter animal movements and cause direct mortality (Jakes and others, 2018). Additional obstacles to ungulate movement include the fragmented mosaic of roads, well pads and other infrastructure associated with oil and gas (Sawyer and others, 2013), wind (Milligan and others, 2021), and solar energy development (Sawyer and others, 2022). Perhaps most significantly, private lands dominate the vast landscapes many migrations require (Gigliotti and others, 2022), and if developed, represent a lasting loss of habitat and landscape connectivity. Although various development forms can reduce corridor functionality (Wyckoff and others, 2018), the development thresholds that populations can tolerate before migratory behavior declines is difficult to study and rarely known (Sawyer and others, 2020). Studies of human development effects on ungulate migrations are further complicated by the likelihood that different species can have species-specific thresholds of human effects they can withstand before migrations are lost (Lambert and others, 2022).

Recognizing the significance of migration in sustaining robust ungulate populations, the U.S. Department of the Interior established Secretarial Order No. 3362 in 2018 to assist State wildlife management agencies with enhancing habitat quality of big game species winter ranges and migration corridors throughout the Western United States (U.S. Department of the Interior, 2018). As part of Secretarial Order No. 3362, the U.S. Geological Survey (USGS) was charged with assisting the Western State wildlife management agencies in mapping migration corridors and winter ranges, which prompted the USGS to establish the Corridor Mapping Team (CMT; Kauffman and others, 2020a). The CMT includes participation from all 11 Western States and from multiple Tribal and Federal agencies and works to design and implement a unified mapping effort for ungulates throughout the Western United States. As part of the effort, the CMT publishes the "Ungulate Migrations of the Western United States" report series, which includes maps and migration details of all included herds and makes the migration maps accessible to a wide range of stakeholders (Kauffman and others 2020a, 2022a, c). The map layers for most of the herds in the report series are also available from Kauffman and others (2020b, 2022b, d). This report, volume 4 in the series, details migrations and seasonal ranges from an additional 33 herds, including updated maps for two herds from Kauffman and others (2020a, 2022a). In aggregate, the report series documents 182 unique herd migrations throughout the Western United States (pl. 1). *Odocoileus hemionus* (mule deer) and *Cervus canadensis* (elk) have been the most commonly mapped species because of the abundance of datasets for both species; however, other species, such as *Antilocapra americana* (pronghorn), *Odocoileus virginianus* (white-tailed deer), *Bison bison* (bison), and *Alces alces* (moose), are included as data are collected, analyzed, and mapped (fig. 1).

As the CMT continues mapping seasonal ungulate movements, the detailed migration maps are increasingly integrated into regional management, conservation, and policy decisions. Volume 3 in the report series described many of the ways the maps are used throughout the Western United States, such as identifying locations where underpasses or overpasses could ease ungulate movements across busy highways (Kauffman and others, 2022c). In this report, we build on the

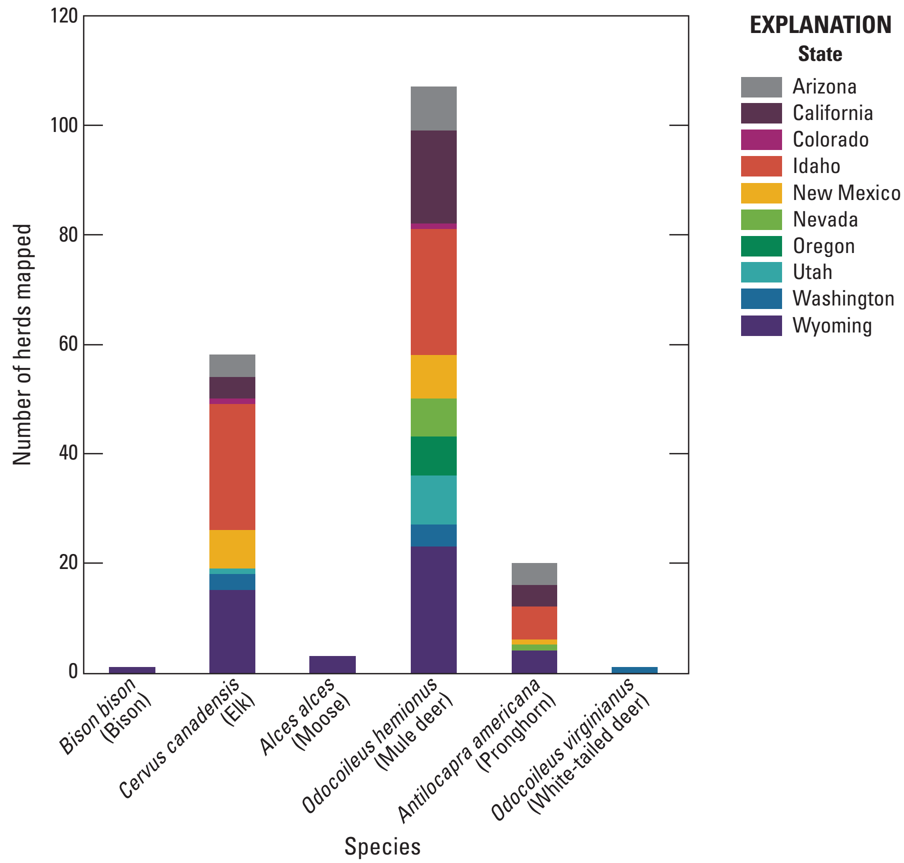


Figure 1. Number of herds mapped by species in this report and Kauffman and others (2020a, 2022a, c). Across the Western United States, 34 of these herds traverse 32 different Tribal lands.

science published in previous reports and focus on additional areas where migration maps can help inform ungulate management and conservation decisions. More specifically, we discuss animal movement in the context of disease dynamics and detail the increased need to document ungulate migrations because of the expanding renewable energy footprint. In addition, Sidebar 1 broadly describes the varying Federal land ownership patterns for lands used by ungulates throughout the Western United States.

Animal Movement and Disease Dynamics

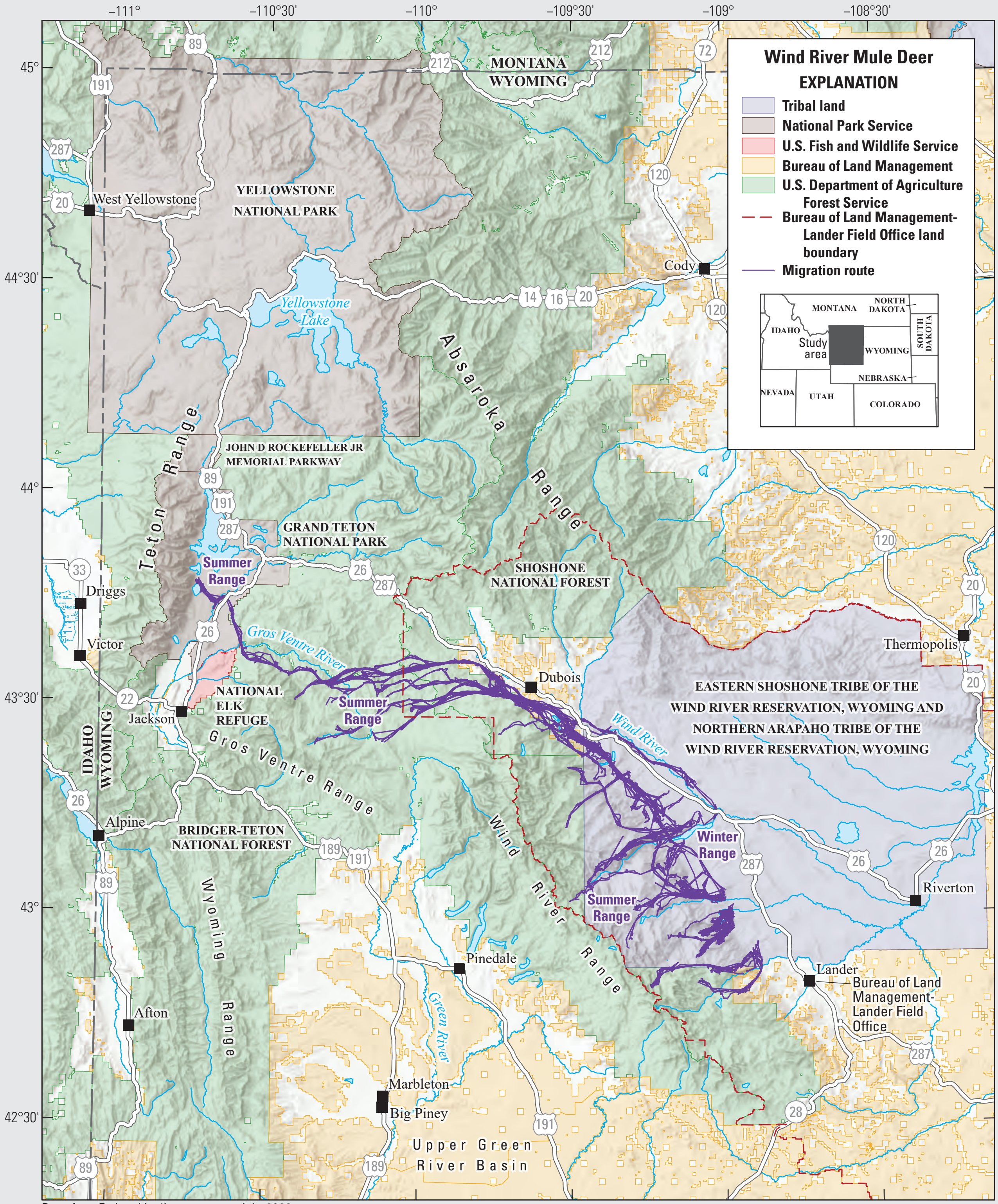
Disease threatens many big game species throughout the Western United States. Most diseases spread through direct (for example, touching) or indirect (for example, environmental contamination) interactions among individuals. Thus, understanding herd social and movement behaviors is key to managing disease prevalence and spread. For instance, the spatial and temporal dynamics of individual hosts moving through the landscape underlie transmission in humans and wild animals (Dougherty and others, 2018; Merkle and others, 2018). Although the large movements of migratory animals can promote disease spread, recent research indicates these movements may also allow hosts to minimize time in infected areas, reduce disease prevalence when compromised individuals die during migration, and facilitate the evolution of less virulent pathogens (Altizer and others, 2011).

The social structure in and among species likely affects disease dynamics. In general, individuals living in closer proximity with higher direct or indirect contact rates should experience higher rates of disease transmission. However, these dynamics can be complex. Migrants can move individually or in groups and be closely associated or dispersed, or in fusion-fission societies where group membership readily changes (Milner-Gulland and others, 2011). For instance, it was long thought group size was a strong indicator of disease transmission. However, support has been mixed; some studies demonstrate higher disease transfer in large groups (Caillaud and others, 2013) and others show higher disease transfer in small groups (Semple and others, 2002). Social structure probably mediates these dynamics. When groups are fluid, any individual may only interact with a few others, but those individuals then interact with others, resulting in a branching network of contacts (Nunn and others, 2015). However, when groups are stable, each group can act as

Sidebar 1. Federal Land Use

The CMT continues to build a framework promoting the long-term functionality of migrations by documenting and describing the seasonal movement patterns throughout the Western United States. Numerous State, regional, and national efforts are working to sustain migration corridors, and maps from this report series can be used to inform regional management, conservation, and policy (Kauffman and others, 2020b, 2022b, d). The CMT provides land summaries supporting the migration maps to Tribal and Federal agencies throughout the Western United States. For example, an analysis of 101 migration maps from Kauffman and others (2020a, 2022a) indicated 83 herds cross 45 Bureau of Land Management (BLM) field office lands, 19 herds cross 11 National Park Service park and monument lands, 22 herds cross 26 Tribal lands, 94 herds cross 33 U.S. Department of Agriculture Forest Service (FS) National Forest lands, and 16 herds cross 16 U.S. Fish and Wildlife Service Refuge lands (fig. 2). Through collaboration among State, Tribal, and Federal partners, the CMT is working to provide the science necessary to advance conservation and management of ungulate migrations in the changing Western United States.

Photograph from Tanner Warder, Wyoming Migration Initiative, University of Wyoming.



Base from Esri and its licensors, copyright 2022
U.S. Geological Survey digital data, 2019
Universal Transverse Mercator, zone 12 north
North American Datum of 1983

0 10 20 30 40 50 MILES
0 10 20 30 40 50 KILOMETERS

Figure 2. Migration of the Wind River mule deer herd as an example of the numerous Federal lands crossed by a single herd. Mule deer inhabit winter ranges primarily on the Wind River Reservation and then cross through the Bureau of Land Management-Lander Field Office land, Shoshone and Bridger-Teton National Forests, the National Elk Refuge, and Grand Teton National Park when migrating to their summer ranges.

an isolated reservoir, thereby decreasing transmission among groups and overall transmission throughout the population (Wilson and others, 2003).

Chronic wasting disease (CWD) is a contagious and fatal prion disease infecting deer, elk, and moose and continues to spread throughout North America (Lubeck, 2020). Prions are transferred by direct contact or indirect pathways, causing stumbling, listlessness, dramatic weight loss, and ultimately death, resulting in subsequent population declines (Monello and others, 2014; DeVivo and others, 2017). Strategies to reduce CWD spread include regulations on (1) carcass management, (2) importing and raising captive deer, and (3) feeding or baiting practices. Population management strategies, such as “test and cull,” and increased harvest of specific population segments, may also prevent or reduce CWD spread (Uehlinger and others, 2016). Because prions can persist on the landscape and prevalence can lag after initial transmission, a proactive or rapid response at the population scale is best. Thus, understanding which herds facilitate CWD spread or increase prevalence may help prioritize management efforts. Doing so involves a better understanding of the movements and social structure (such as, group size and density and fusion-fission dynamics) of herds.

Of particular interest, CWD is now present in large parts of the Greater Yellowstone Ecosystem (GYE; Cotterill and others, 2018; Wyoming Game and Fish Department, 2022a; fig. 3*A*, *B*), one of the largest, intact temperate ecosystems in the world. The GYE is a highly dynamic system with individuals traveling as much as 150 miles (mi; 241 kilometers [km]) during a single migration (Middleton and others, 2020). The GYE also comprises Federal, Tribal, and private lands and is a useful study system to help understand CWD spread in ungulates. Migratory individuals with CWD potentially could spread the disease along migration corridors and to other herds, although this scenario has never been documented. Nonetheless, CWD spread is probably affected by migration distance, timing, and social attributes such as group size, time spent together, and interactions in and among herds. An understanding of these relations can help wildlife managers in the GYE identify probable routes of transmission and make informed surveillance area decisions.

To understand how migratory movements can potentially mediate direct and indirect disease transmission, we analyzed movement data from mule deer in the Wyoming segment of the GYE as an illustrative example. We used a social network analysis framework (Farine and Whitehead, 2015). Hunt areas and national parks were represented by network nodes, and network edges represented connections between those areas based on the movements of GPS-collared mule deer (fig. 4). This analysis indicated four patterns: (1) strong mixing of mule deer in the Upper Green River Basin of Wyoming is apparent; (2) strong one-way movements occurred from the southern part of the Red Desert into the Upper Green River area, which includes the 200-mi (322-km) Red Desert to Hoback migration (Kauffman and others, 2020a); (3) gaps are apparent in the landscape where very few, if any, mule deer move through hunt areas (for example, the northeast to the southwest side of the Wind River Range); and (4) in some summer or winter ranges, such as in the core of the GYE, mule deer captured in different areas overlap, like individuals captured in Cody and Dubois, Wyoming, which overlapped on summer ranges. The findings from this initial effort highlighted the link among animal movement and sociality and the potential for disease spread. Migratory animals often share migration corridors, as shown in Kauffman and others (2020a, 2022a, c), and the results from this study indicated ample mixing of mule deer in hunt areas. An understanding of where individuals from different winter ranges overlap on summer ranges, which herds have overlapping migration corridors, and the direction of these movements can help wildlife managers understand and predict where to expect diseases to spread. As CWD continues to spread throughout the Western United States, understanding how the social structure in and among herds affects disease can play a crucial role in informing regional management decisions.

Potential Effects of Renewable Energy Development to Ungulate Populations

Renewable energy has developed rapidly throughout the United States and advances towards carbon neutrality rely heavily on the expansion of wind and utility-scale solar (greater than [>]1 megawatt) development (Larson and others, 2021). The United States added more than 13 gigawatts of wind power in 2021, and much of that occurred in the Western and southwestern States (Wiser and others, 2022). Advances in turbine technology facilitated this expansion, allowing wind development in regions with lower average wind speeds (Wiser and others, 2022). Aligning with the rapid pace of wind energy development, ground-mounted photovoltaic solar energy is expected to grow from 3 to 40 percent of the U.S. energy supply by 2035 (Wiser and others, 2022). Solar energy has the lowest life-cycle greenhouse gas emissions (Hernandez and others, 2015) and most solar development now occurs on private lands; however, the Department of the Interior directed the BLM to update their Solar Programmatic Environmental Impact Statement in 2023 to accelerate solar development on Federal lands (U.S. Department of the Interior, 2022). Support for alternative energies is also common at the State level, and many Governors in the Western United States support increases in renewable energy development. Similar patterns have been observed throughout the Tribal lands of the Western United States, which have had increases in the number of solar projects from private companies and Tribal-owned utilities (J. Fort, Navajo Nation Department of Fish and Wildlife, written commun., 2023).

As the renewable energy footprint expands, so do the potential effects to ungulates, including direct and indirect habitat loss and the creation of new barriers to ungulate movement (Milligan and others, 2023; Sawyer and others, 2020, 2022). To date, research on ungulates and renewable

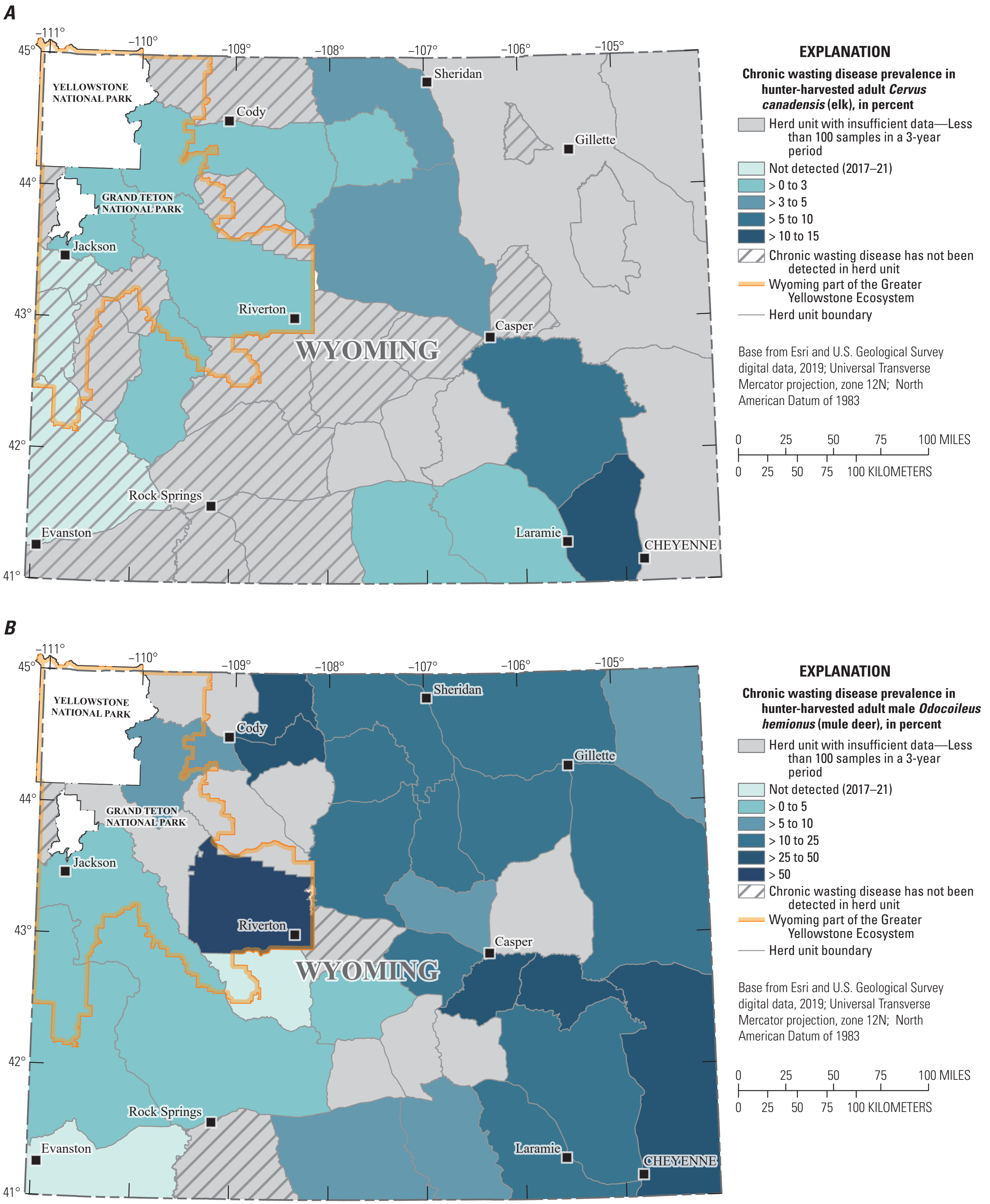


Figure 3. Percentage of chronic wasting disease prevalence in hunter-harvested adult *A, Cervus canadensis* (elk) and hunter-harvested adult male *B, Odocoileus hemionus* (mule deer) by herd unit in Wyoming. The prevalence levels and “Not detected” classification are specific to the study period, 2017–21. [>, greater than]

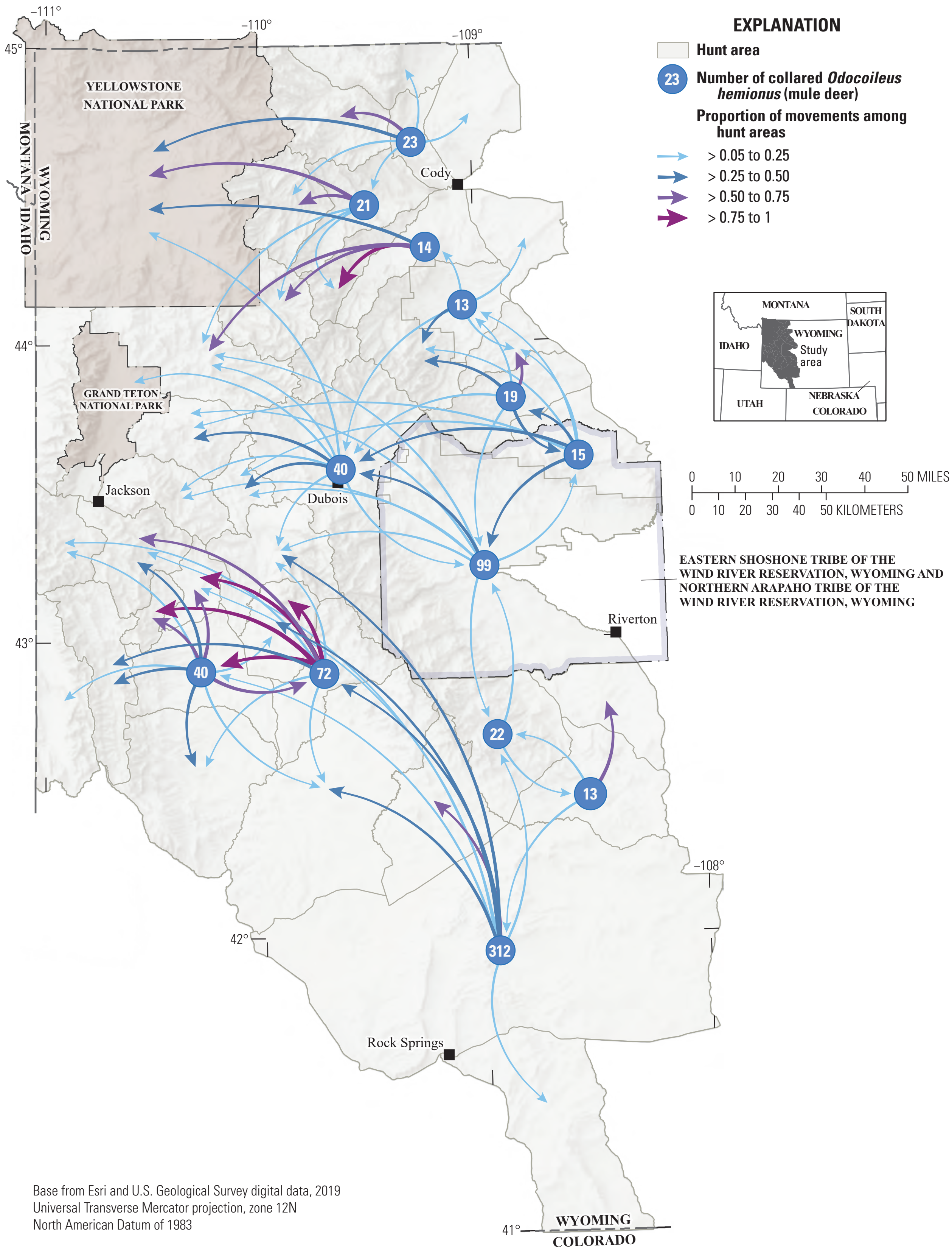


Figure 4. Movements of *Odocoileus hemionus* (mule deer) in mule deer hunt areas and national parks in northwestern Wyoming. Hunt areas with less than 10 global positioning system (GPS)-collared mule deer, and a proportion of movements from 0.05 of GPS-collared mule deer, are not shown on the figure.

energy development is limited, but recent studies suggest ungulates can access habitat and move through wind facilities. However, migratory behaviors like speed, fidelity, and stopover use can be altered (Milligan and others, 2023), and pronghorn in Wyoming sometimes avoid turbines during the winter (Smith and others, 2020; Milligan and others, 2021). Wind energy projects can encompass thousands of acres, but the amount of direct habitat lost to infrastructure is small (Allison and others, 2019). In contrast, the effects of utility-scale solar projects are evident in the amount of land required. Ungulates cannot access or move through utility-scale solar energy projects because current design recommendations include 6- to 8-foot (ft; 1.8- to 2.4-meter [m]) security fencing impermeable to larger mammals. Thus, when located in an ungulate's range, solar farms result in a loss of habitat and can create barriers to movement for resident and migratory animals (Sawyer and others, 2022). Additionally, when sited adjacent to highways, solar farms can inadvertently increase the risk of wildlife-vehicle collisions (WVC; Martin, 2019).

Regardless of the energy development type, the mitigation hierarchy, whereby stakeholders seek to avoid, minimize, or mitigate potential effects on wildlife, is the default planning tool for land managers. For ungulates, avoidance and minimization measures are largely shown by spatial data that identify critical habitats, like winter range and migration corridors. Accordingly, the ungulate movement data that have been analyzed and mapped in the "Ungulate Migrations of the Western United States" report series (Kauffman and others, 2020a, 2022a, c) provide a key resource to help site renewable energy projects and design project layouts that minimize effects to critical habitat. Maps of ungulate migrations have been used for years to inform and modify leasing decisions for oil and gas development, including lease buyouts and lease sales removal (Kauffman and others, 2021b). Given the massive land requirements for carbon-neutral pathways (Larson and others, 2021), detailed maps of migrations and other seasonal movements—like those provided by the CMT's efforts—will increasingly be needed to retain permeable landscapes for ungulates in regions targeted for renewable energy development.

Herd Summaries

The herd-specific maps and associated summary text are the core information of the "Ungulate Migrations of the Western United States" report series. We provide maps documenting the migrations of 33 mule deer, pronghorn, and elk herds in most Western States and select Tribal lands. These maps were produced in close collaboration with participating State or Tribal agencies that provided the GPS-collar data. The respective habitat areas for each herd vary based on local-level policies and may include migration routes (lines) or corridors (polygons), stopovers, winter ranges, or annual ranges. In addition to the herd maps, we provide project and analytical details, summary statistics for the underlying data, and relevant contacts and reports. The general workflow for each herd's data analysis consisted of the following steps: (1) selecting migration dates for each animal year using the Migration Mapper application (Merkle and others, 2022), (2) using a Brownian bridge movement model to estimate a unique utilization distribution (UD) for each migration sequence (Horne and others, 2007), (3) averaging the UD for a given individual's migration sequences for all years, and (4) stacking the averaged individual UD for a given herd and defining different levels of migration-route use based on the number of individuals using a given pixel, or defined area of space. In general, we defined "low use" as areas traversed by at least 1 collared individual during migration, "medium use" as areas used by >10 percent of collared individuals in the herd, and "high use" as areas used by >20 percent of collared individuals in the herd. However, some States and Tribes adapted these general methods to adhere to agency-specific methodologies. A complete description of the methods and herd-specific modifications is included in appendix 1. These page pairs provide an overview of the documented ungulate migrations throughout the Western United States and serve as an additional tool to help inform local and regional management and conservation decisions. The data layers for many of the herd maps in this report are also publicly available in the associated USGS data release (Kauffman and others, 2024).

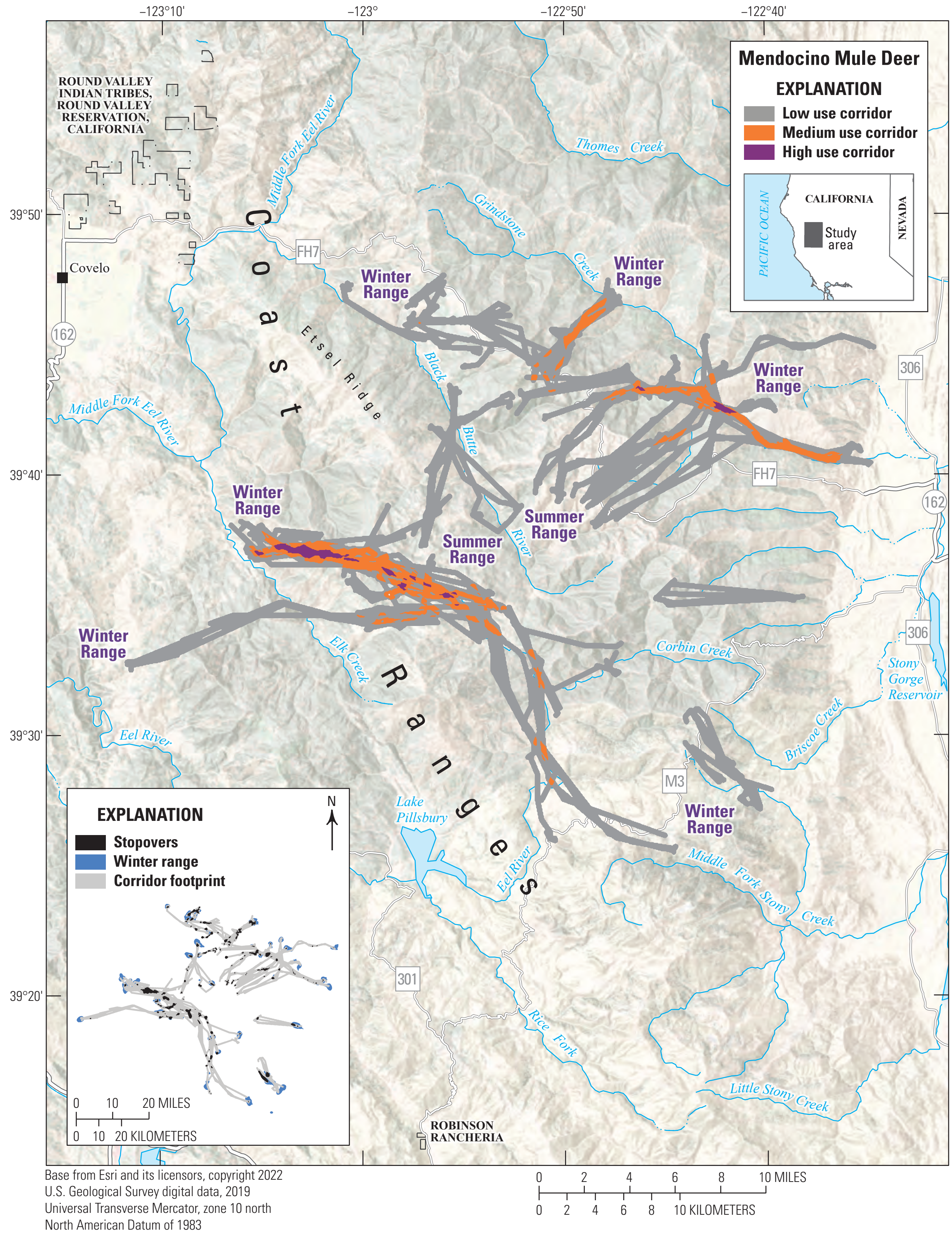


Figure 5. Migration corridors, stopovers, summer ranges, and winter ranges of the Mendocino mule deer herd.

California | Mule Deer

Mendocino Mule Deer

The Mendocino mule deer herd complex comprises three overlapping *Odocoileus hemionus columbianus* (black-tailed deer) administrative herds, including Mendocino, Clear Lake, and Alder Springs. Mendocino black-tailed deer exhibit variable movement patterns and strategies, including traditional seasonal migrants, multirange migrants, and full-time residents. Migrants move between seasonal ranges from a multitude of lower elevation areas in the northern Coast Range in winter to higher elevation summer ranges (fig. 5). With a larger dataset, local biologists predict finding high use winter ranges throughout foothill slopes and valley bottoms for this herd's range. Female deer of the Mendocino herd complex exhibit short-term (seasonal and [or] annual) and long-term (multigenerational) fidelity to their summer ranges (Bose and others, 2017). Population density estimates based on fecal pellet deoxyribonucleic acid (DNA) collected in 2011 and 2012 indicated exceptionally high deer densities on productive summer ranges (131.44 deer per square mile [mi^2]; 50.75 deer per square kilometer [km^2]; Lounsberry and others, 2015). However, the herd was declining considerably during this period (2011–12) because of low adult survival, including of prime-aged females (Marescot and others, 2015); survival rates were lower than typically observed in other herds (Forrester and Wittmer, 2013). Predation from *Ursus americanus* (black bears) and *Canis latrans* (coyotes) was the primary cause of low annual survival of fawns (Forrester and Wittmer, 2019), whereas predation from *Puma concolor* (mountain lion) was the foremost cause of adult female mortality (Marescot and others, 2015), often in areas deemed less familiar to the individual deer (Forrester and others, 2015). Mountain lion kill rates of black-tailed deer in the study area were the highest reported for their range (Cristescu and others, 2022), probably because of high rates of kleptoparasitism from black bears (Elbroch and others, 2015; Allen and others, 2021). More recent research from California Department of Fish and Wildlife focused on collecting DNA from fecal pellets to update population density estimates (California Department of Fish and Wildlife, 2015) and to determine the herd's response to catastrophic wildfire (California Department of Fish and Wildlife, 2019; California Department of Forestry and Fire Protection, 2021). Habitat use by black-tailed deer (Bose and others, 2018) and their predators (Cristescu and others, 2019) in the area is well understood, and most of the habitats occupied by the Mendocino herd complex are protected and not at risk of development or fragmentation. However, the threat of catastrophic wildfire and climate change-induced landscape scale changes exist.

Animal Capture and Data Collection

Sample size: 89 adult female mule deer
Relocation frequency: Approximately 1−13 hours
Project duration: 2004–13 and 2017–21

Data Analysis

Stopover and winter range analysis: Fixed Motion Variance; corridor analysis used the line buffer method where lines from migration sequences were buffered by 656 ft (200 m; Merkle and others, 2023; refer to app. 1 for further description).

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

Models derived from:

- Migration: 125 sequences from 50 individuals (56 spring sequences, 69 fall sequences)
- Winter: 65 sequences from 45 individuals

Migration use classifications:

- Low: Used by at least one individual
- Medium: Used by 10–20 percent of the individuals
- High: Used by >20 percent of the individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: April 30 to May 6
- Fall: October 6 to October 14

Number of days migrating (mean):

- Spring: 7 days
- Fall: 8 days

Migration corridor length:

- Minimum: 1.07 mi (1.73 km)
- Mean: 6.95 mi (11.19 km)
- Maximum: 15.48 mi (24.92 km)

Migration corridor area:

- Low use: 75,594 acres (30,592 hectares [ha])
- Medium use: 9,355 acres (3,786 ha)
- High use: 1,068 acres (432 ha)
- Stopover area: 7,851 acres (3,177 ha)

Winter Range Summary

Winter start and end dates (median):

- October 21 to May 14
- Winter length (mean): 218 days
- Winter range area: 18,229 acres (7,377 ha)

Other Information

Project contacts:

- Heiko Wittmer (heiko.wittmer@vuw.ac.nz), Professor, Victoria University of Wellington, New Zealand
- Josh Bush (joshua.bush@wildlife.ca.gov), Senior Environmental Scientist, California Department of Fish and Wildlife

Data analyst:

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

Reports and publications:

- Wittmer, H.U., Forrester, T.D., Allen, M.L., Marescot, L., and Casady, D.S., 2014, Black-tailed deer population assessment in the Mendocino National Forest, California Final Project Report—December 2014: Sacramento, Calif., California Department of Fish and Wildlife, 56 p. [Also available at https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=153193.]

Photograph from Heiko U. Wittmer, Victoria University of Wellington.

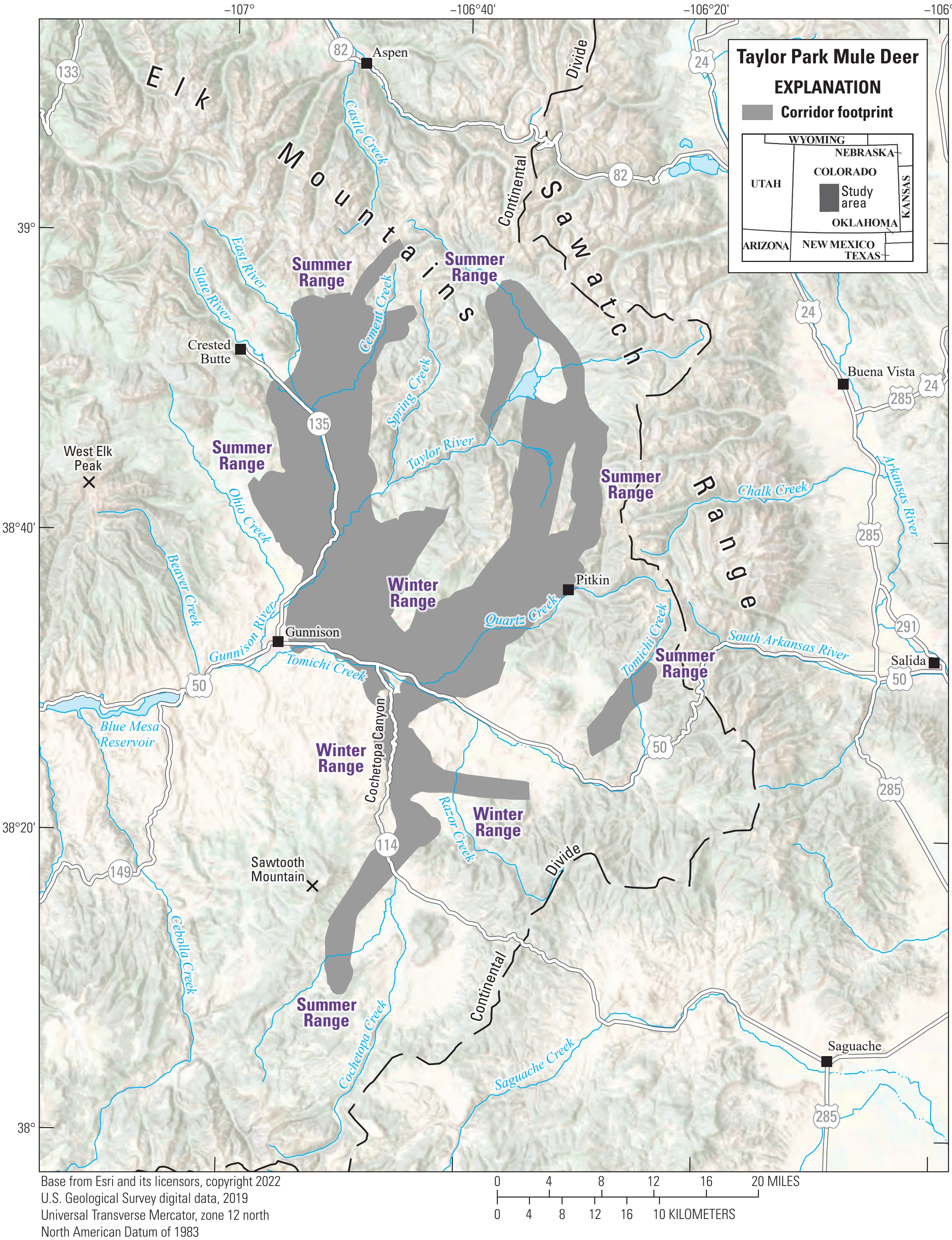


Figure 6. Migration footprint, summer ranges, and winter ranges of the Taylor Park mule deer herd.

Colorado | Mule Deer

Taylor Park Mule Deer

The Taylor Park mule deer herd (Data Analysis Unit D22) inhabits the central part of southwest Colorado (fig. 6) and overlaps with the East Gunnison Basin elk herd (refer to the “East Gunnison Basin Elk” section in this report). The unit encompasses approximately 1,432 mi^2 (3,709 km^2) and is bound on the north by the Elk Mountains and Sawatch Range; on the east and south by the Continental Divide; and on the west by the East River, Gunnison River, and Cochetopa Creek. Elevations in the unit range from approximately 7,700 ft (2,347 m) near Gunnison, Colorado, to more than 14,000 ft (4,267 m) along the Continental Divide. The unit comprises a mix of land ownership and approximately 88 percent public lands. Most private lands are at lower elevations in the unit. Historically, the Taylor Park mule deer herd ranged from 5,000 to 10,000 mule deer, and the current estimate is 6,500 individuals.

During the winters of 2013–22, GPS collars were deployed on 71 adult female mule deer, with two main goals: (1) to measure annual survival rates, and (2) to understand long-term changes in distribution and movement patterns. Although most of the herd summers and winters in this unit, data indicated some individuals summer in the neighboring West Elk unit and some individuals winter in the adjacent Powderhorn unit to the west and southwest, respectively. During early and mild winters, mule deer are distributed throughout the winter range, which includes sagebrush and *Populus* spp. (aspen) woodland communities at midelevations. As winter severity increases, a commensurate proportion of mule deer move to lower elevations and concentrate along U.S. Highway 50 or the steeper south-facing slopes, such as slopes found in the Cochetopa Canyon along State Route 114 in the southwest section of the Taylor Park mule deer range. The severity of winter conditions amplifies the number of WVC along U.S. Highway 50 east of Gunnison either because mule deer migrate to the Cochetopa Canyon (5–10 mi [8–16 km] away) or because U.S. Highway 50 bisects their winter range. Wintering mule deer face harsh winter conditions with deep snow covering available food sources, causing extreme die offs approximately every 10 years. Ensuring mule deer can continue to move to critical winter range and safely cross roads are conservation priorities for this herd. Many of the same corridors and pinch points used by the Taylor Park mule deer herd overlap with the East Gunnison Basin elk herd.

Animal Capture and Data Collection

Sample size: 71 adult female mule deer

Relocation frequency: Approximately 12.5–13 hours

Project duration: 2013–present (data through November 2021 analyzed for this report)

Data Analysis

Corridor analysis: Fixed Motion Variance (refer to app. 1 for further description)

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

Models derived from:

- Migration: 222 sequences from 52 individuals (123 spring sequences, 99 fall sequences)

Migration use classifications:

- Overall footprint: Any migration area used by greater than or equal to 10 percent of the individuals

Corridor Summary

Migration start and end dates (median):

- Spring: May 2 to May 25
- Fall: October 21 to November 5

Number of days migrating (mean):

- Spring: 25 days
- Fall: 28 days

Migration corridor length:

- Minimum: 3.44 mi (5.53 km)
- Mean: 17.50 mi (28.16 km)
- Maximum: 44.69 mi (71.92 km)

Migration corridor area:

- Overall footprint: 343,007 acres (138,810 ha)

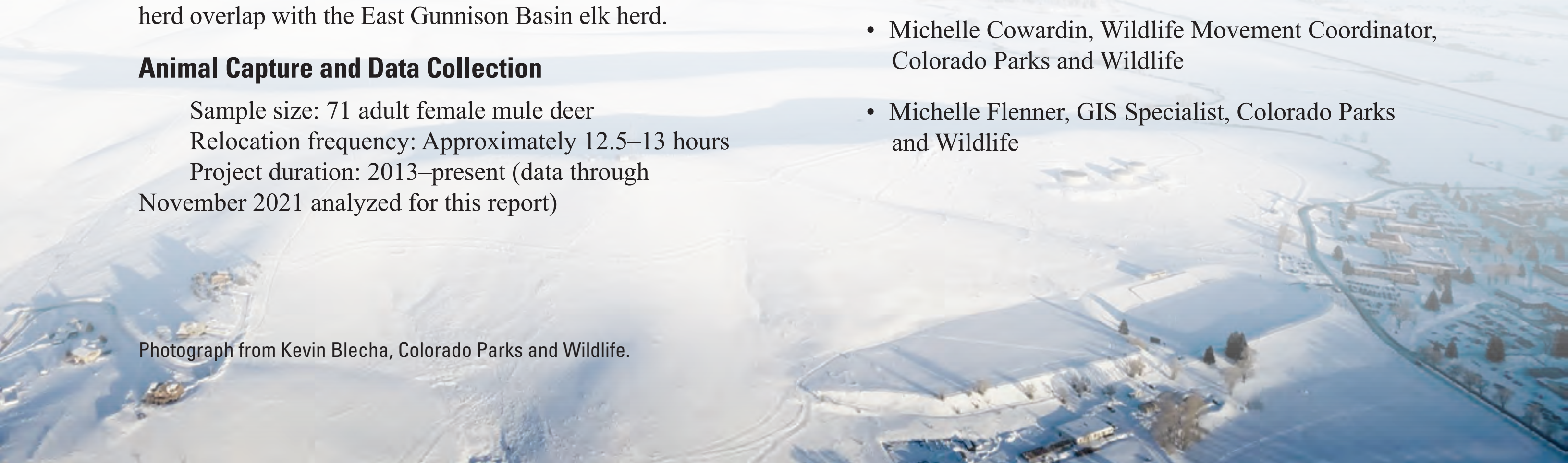
Other Information

Project contacts:

- Kevin Blecha (kevin.blecha@state.co.us), Wildlife Biologist, Colorado Parks and Wildlife
- Andy Holland (andy.holland@state.co.us), Big Game Manager, Colorado Parks and Wildlife

Data analysts:

- Chloe Beaupre, Graduate Research Assistant, Western Colorado University, Clark School of Environment and Sustainability
- Michelle Cowardin, Wildlife Movement Coordinator, Colorado Parks and Wildlife
- Michelle Flenner, GIS Specialist, Colorado Parks and Wildlife



Photograph from Kevin Blecha, Colorado Parks and Wildlife.

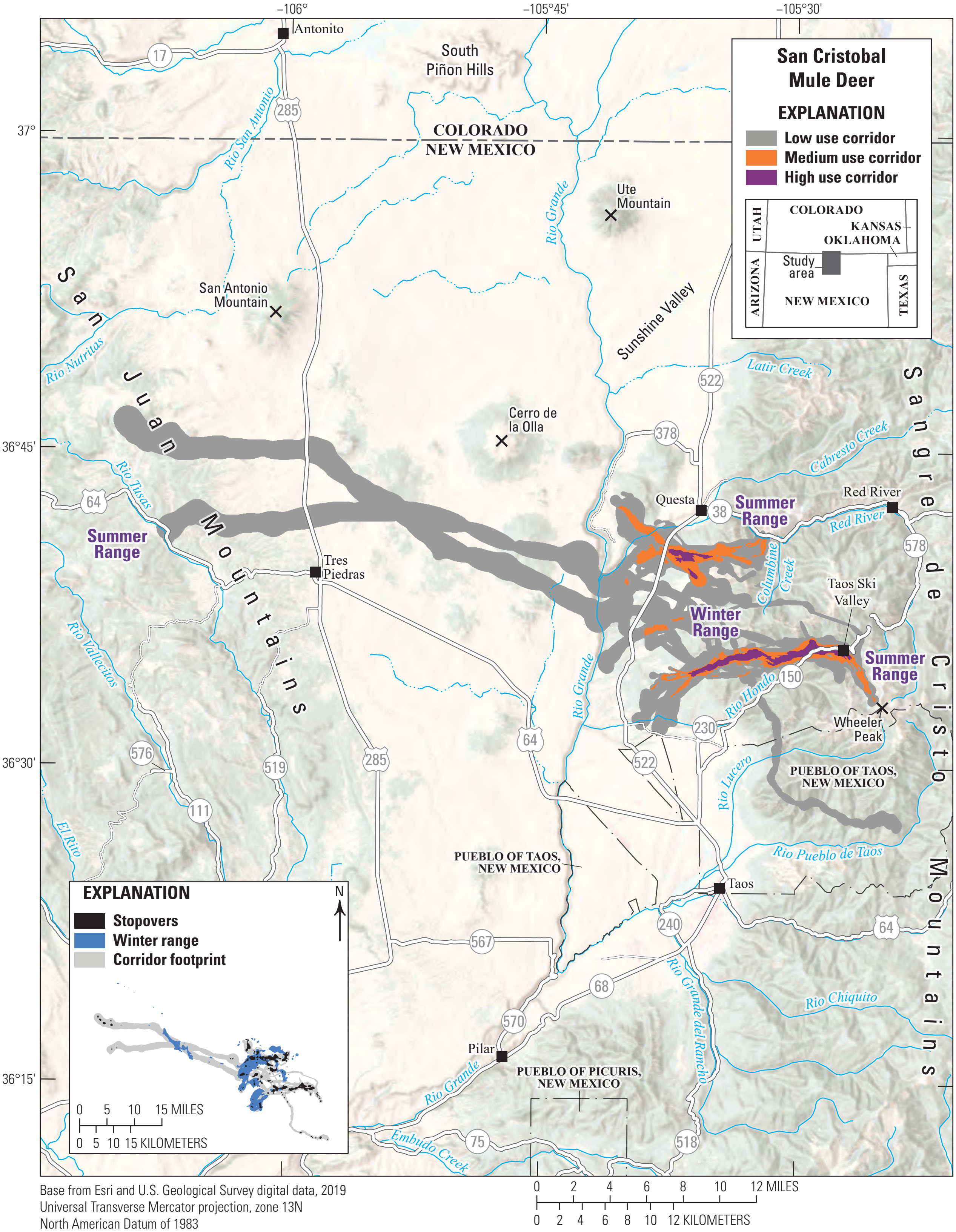


Figure 7. Migration corridors, stopovers, summer ranges, and winter ranges of the San Cristobal mule deer herd.

New Mexico | Mule Deer

San Cristobal Mule Deer

The San Cristobal mule deer herd uses a patchwork of winter ranges in the western foothills of the Sangre de Cristo Mountains south of Questa, New Mexico (fig. 7). Winter ranges, bisected by State Route 522, are shared by deer that migrate east and west to summer ranges in the Sangre de Cristo and San Juan Mountains, respectively. The mule deer use multiple migration corridors; most of the herd migrates east into regional national forest and wilderness areas, using shorter, eastern corridors in the Sangre de Cristo Mountains. However, some individuals migrate west from shared winter ranges, moving across U.S. Highway 285, to summer ranges in the San Juan Mountains. *Quercus* spp. (oak) woodlands, *Pinus ponderosa* (ponderosa pine), aspen, and mixed-conifer forests characterize the eastern corridors and sagebrush steppe, grasslands, *Pinus* spp. (pinyon)-juniper mesas, oak woodlands, ponderosa pine, aspen, and mixed-conifer forests characterize the western corridors and stopovers. The eastern corridor is split into two main sections, one heading north and the other heading south. The northern route terminates south of the Red River and west of Columbine Creek. The southern route terminates near Taos Ski Valley northwest of Wheeler Peak, New Mexico's highest peak (13,167 ft [4,013 m]). Challenges for this herd include potential development on winter ranges and crossing State Route 522 and U.S. Highway 285.

Animal Capture and Data Collection

Sample size: 26 adult female mule deer
Relocation frequency: Approximately 2 hours
Project duration: 2021–present (data through January 2023 analyzed for this report)

Data Analysis

Corridor, stopover, and winter range analysis: Brownian bridge movement models (Sawyer and others, 2009) and Fixed Motion Variance (refer to app. 1 for further description)
Delineation of migration periods: Net Squared Displacement (Bunnefeld and others, 2011)
Models derived from:

- Migration: 58 sequences from 23 individuals (28 spring sequences, 30 fall sequences)
- Winter: 11 sequences from 11 individuals

Migration use classifications:

- Low: Used by at least one individual
- Medium: Used by 10–20 percent of the individuals
- High: Used by >20 percent of the individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: May 6 to May 16
- Fall: October 19 to November 2

Number of days migrating (mean):

- Spring: 10 days
- Fall: 15 days

Migration corridor length:

- Minimum: 1.06 mi (1.70 km)
- Mean: 10.53 mi (16.95 km)
- Maximum: 28.69 mi (46.17 km)

Migration corridor area:

- Low use: 89,916 acres (36,388 ha)
- Medium use: 9,551 acres (3,865 ha)
- High use: 2,618 acres (1,059 ha)
- Stopover area: 10,118 acres (4,095 ha)

Winter Range Summary

Winter start and end dates (median):

- November 5 to May 6
- Winter length (mean): 194 days
- Winter range area: 27,017 acres (10,933 ha)

Other Information

Project contacts:

- Orrin Duvuvuei (orrin.duvuvuei@dgf.nm.gov), Deer Program Manager, New Mexico Department of Game and Fish
- Nicole Tatman (Nicole.Tatman@dgf.mm.gov), Big Game Program Manager, New Mexico Department of Game and Fish

Data analyst:

- Craig Reddell, GIS Analyst, New Mexico State University

Photograph from Orrin Duvuvuei, New Mexico Department of Game and Fish.

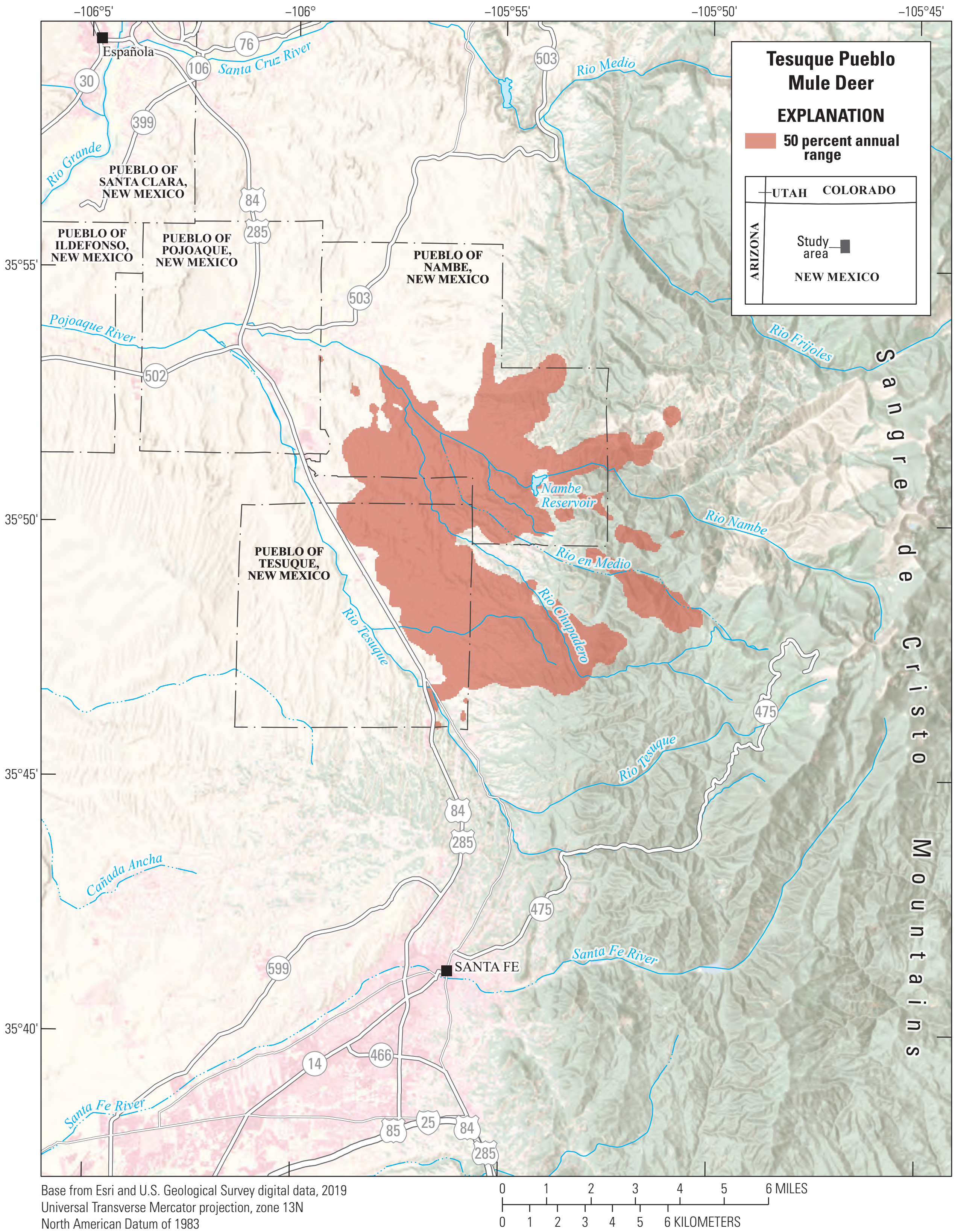


Figure 8. Annual range for the Tesuque Pueblo mule deer herd.

New Mexico | Mule Deer

Tesuque Pueblo Mule Deer

The Tesuque Pueblo mule deer herd is primarily nonmigratory, using the foothills of the Sangre de Cristo Mountains (fig. 8). U.S. Highways 84 and 285 are the major routes from Santa Fe, New Mexico, to areas in northern New Mexico and southern Colorado, bisecting Pueblo of Tesuque, New Mexico, and creating a physical barrier for deer movement. GPS collars were deployed on 6 mule deer (3 females and 3 males) to identify where mitigation efforts, like installing underpasses or fencing, may help mule deer cross busy highways successfully and reduce the number of WVC. The female mule deer primarily used the northeastern part of Pueblo of Tesuque, New Mexico, and the southeastern parts of the Pueblo of Nambe, New Mexico. The male mule deer primarily inhabited the urban private lands adjacent to the eastern boundary of Pueblo of Tesuque, New Mexico. Their annual range (50 percent contour) primarily consists of pinyon-juniper woodlands and pinyon-juniper savannahs. The mule deer are culturally significant to the Pueblo of Tesuque, New Mexico, Tribal members.

Animal Capture and Data Collection

Sample size: 6 adult mule deer (3 males, 3 females)
Relocation frequency: Approximately 4 hours
Project duration: 2018–21

Data Analysis

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

Models derived from:

- Annual range: 14 sequences from 6 individuals

Annual Use Summary

- Annual range (50 percent contour) area: 19,922 acres (8,062 ha)

Other Information

Project contact:

- Patrick Ryan Swazo-Hinds (rswazohinds@pueblooftesuque.org), Environmental Biologist, Pueblo of Tesuque Department of Environment and Natural Resources

Data analyst:

- Hall Sawyer, Research Biologist, Western Ecosystems Technology, Inc.

Photograph from Joseph Abeyta, Pueblo of Tesuque Department of Environment and Natural Resources.

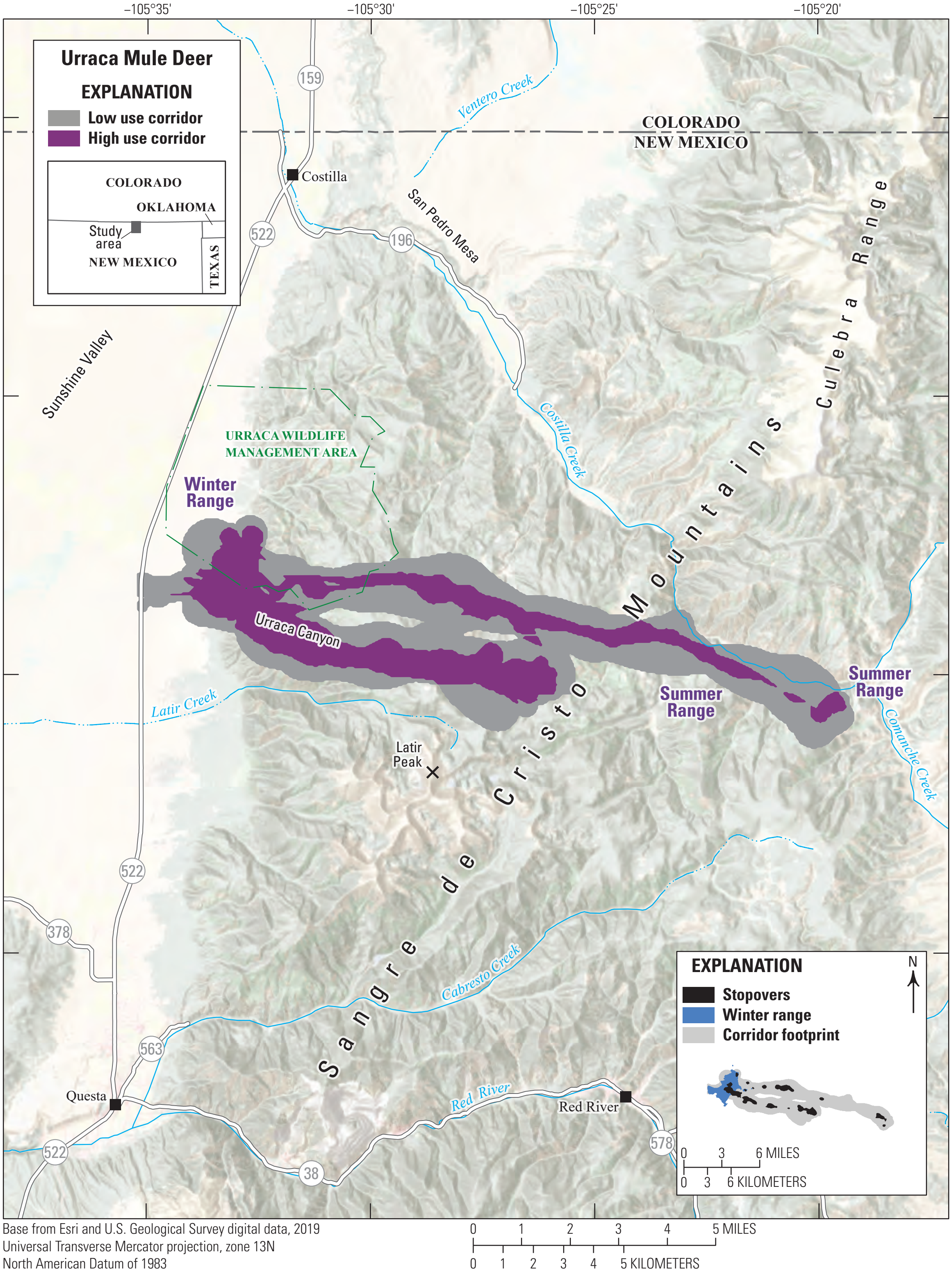


Figure 9. Migration corridors, stopovers, summer ranges, and winter ranges of the Urraca mule deer herd.

New Mexico | Mule Deer

Urraca Mule Deer

The Urraca mule deer herd inhabits an area north of Questa in north-central New Mexico, on the eastern side of Sunshine Valley and the western base of the Sangre de Cristo Mountains (fig. 9). The winter range primarily comprises sagebrush flats east of State Route 522. The mule deer use two primary migration corridors spanning the Urraca Wildlife Management Area and a mosaic of private lands. The southern corridor follows the Urraca Canyon east and terminates at an approximate elevation of 11,000 ft (3,353 m). The northern corridor runs north of Urraca Canyon and ends southwest of the confluence of Costilla Creek and Comanche Creek in New Mexico, at 9,500 ft (2,896 m). Dense conifer and aspen forests interspersed with meadows and creeks characterize the corridors and stopovers. High-elevation summer ranges are northeast of Latir Peak (12,670 ft [3,861 m]).

Animal Capture and Data Collection

Sample size: 9 adult female mule deer

Relocation frequency: Approximately 2 hours

Project duration: 2021–present (data through January 2023 analyzed for this report)

Data Analysis

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

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

Models derived from:

- Migration: 20 sequences from 8 individuals (10 spring sequences, 10 fall sequences)
- Winter: 2 sequences from 2 individuals

Migration use classifications:

- Low: Used by at least one individual
- High: Used by >30 percent of the individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: May 6 to May 8
- Fall: October 24 to November 4

Number of days migrating (mean):

- Spring: 4 days
- Fall: 7 days

Migration corridor length:

- Minimum: 4.32 mi (6.96 km)
- Mean: 9.36 mi (15.06 km)
- Maximum: 13.25 mi (21.32 km)

Migration corridor area:

- Low use: 17,748 acres (7,182 ha)
- High use: 7,020 acres (2,841 ha)
- Stopover area: 2,001 acres (810 ha)

Winter Range Summary

Winter start and end dates (median):

- November 4 to May 3
- Winter length (mean): 174 days
- Winter range area: 2,151 acres (870 ha)

Other Information

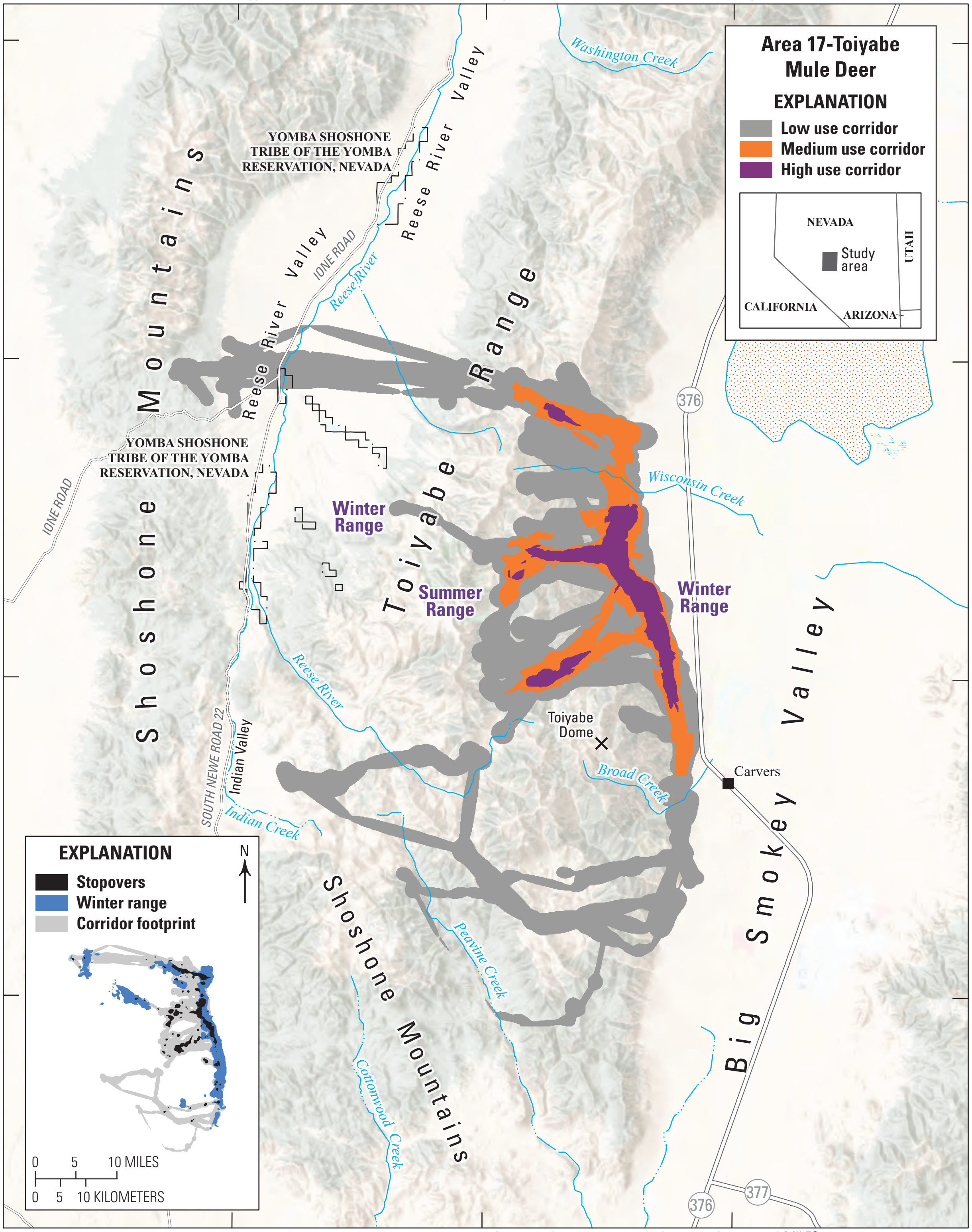
Project contacts:

- Orrin Duvuvuei (orrin.duvuvuei@dgf.nm.gov), Deer Program Manager, New Mexico Department of Game and Fish
- Nicole Tatman (Nicole.Tatman@dgf.nm.gov), Big Game Program Manager, New Mexico Department of Game and Fish

Data analyst:

- Craig Reddell, GIS Analyst, New Mexico State University

Photograph from Orrin Duvuvuei, New Mexico Department of Game and Fish.



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

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

Figure 10. Migration corridors, stopovers, summer ranges, and winter ranges of the Area 17-Toiyabe mule deer herd.

Nevada | Mule Deer

Area 17-Toiyabe Mule Deer

The Area 17-Toiyabe mule deer herd inhabits the Shoshone Mountains and Toiyabe Range, which run north to south in central Nevada (fig. 10). Mule deer from the Shoshone Mountains and Toiyabe Range are characterized by short distance migrations from high elevations above 7,874 ft (2,400 m), down to 5,577 ft (1,700 m). Since the 1920s, the lower elevation slopes east of Toiyabe Dome, between Wisconsin Creek and Broad Creek and locally known as Toiyabe bench, have been documented by the Nevada Department of Wildlife as crucial mule deer winter range. Because of the value of this habitat for mule deer, the BLM closed the area to domestic livestock grazing in 1983 (Nevada Department of Wildlife, Bureau of Land Management, and Toiyabe National Forest, 1985). In 2018, in collaboration with Nevada Department of Wildlife, the FS treated 2,600 acres (647 ha) of pinyon and juniper—thinning the woody vegetation wherever they encroached shrublands—on the crucial mule deer wintering habitat (Gundlach, 2022). Other pinyon and juniper treatments are ongoing in Indian Valley, which is an area of high importance for year-round mule deer habitat between the Shoshone Mountains and Toiyabe Range. Senescent browse, reduced forbs, drought, and pinyon and juniper encroachment are the greatest conservation challenges the Area 17-Toiyabe mule deer herd face.

Animal Capture and Data Collection

Sample size: 36 adult female mule deer
Relocation frequency: Approximately 2–5 hours
Project duration: 2018–21

Data Analysis

Corridor, stopover, and winter range analysis: Fixed Motion Variance (refer to app. 1 for further description)

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

Models derived from:

- Migration: 98 sequences from 35 individuals (63 spring sequences, 35 fall sequences)
- Winter: 47 sequences from 27 individuals

Migration use classifications:

- Low: Used by at least one individual
- Medium: Used by 10–20 percent of the individuals
- High: Used by >20 percent of the individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: April 28 to May 4
- Fall: February 18 to February 22

Number of days migrating (mean):

- Spring: 6 days
- Fall: 5 days

Migration corridor length:

- Minimum: 1.63 mi (2.63 km)
- Mean: 6.03 mi (9.71 km)
- Maximum: 15.22 mi (24.49 km)

Migration corridor area:

- Low use: 73,552 acres (29,765 ha)
- Medium use: 15,886 acres (6,429 ha)
- High use: 5,463 acres (2,211 ha)
- Stopover area: 8,242 acres (3,335 ha)

Winter Range Summary

Winter start and end dates (median):

- February 22 to April 30
- Winter length (mean): 106 days
- Winter range area: 26,278 acres (10,634 ha)

Other Information

Project contacts:

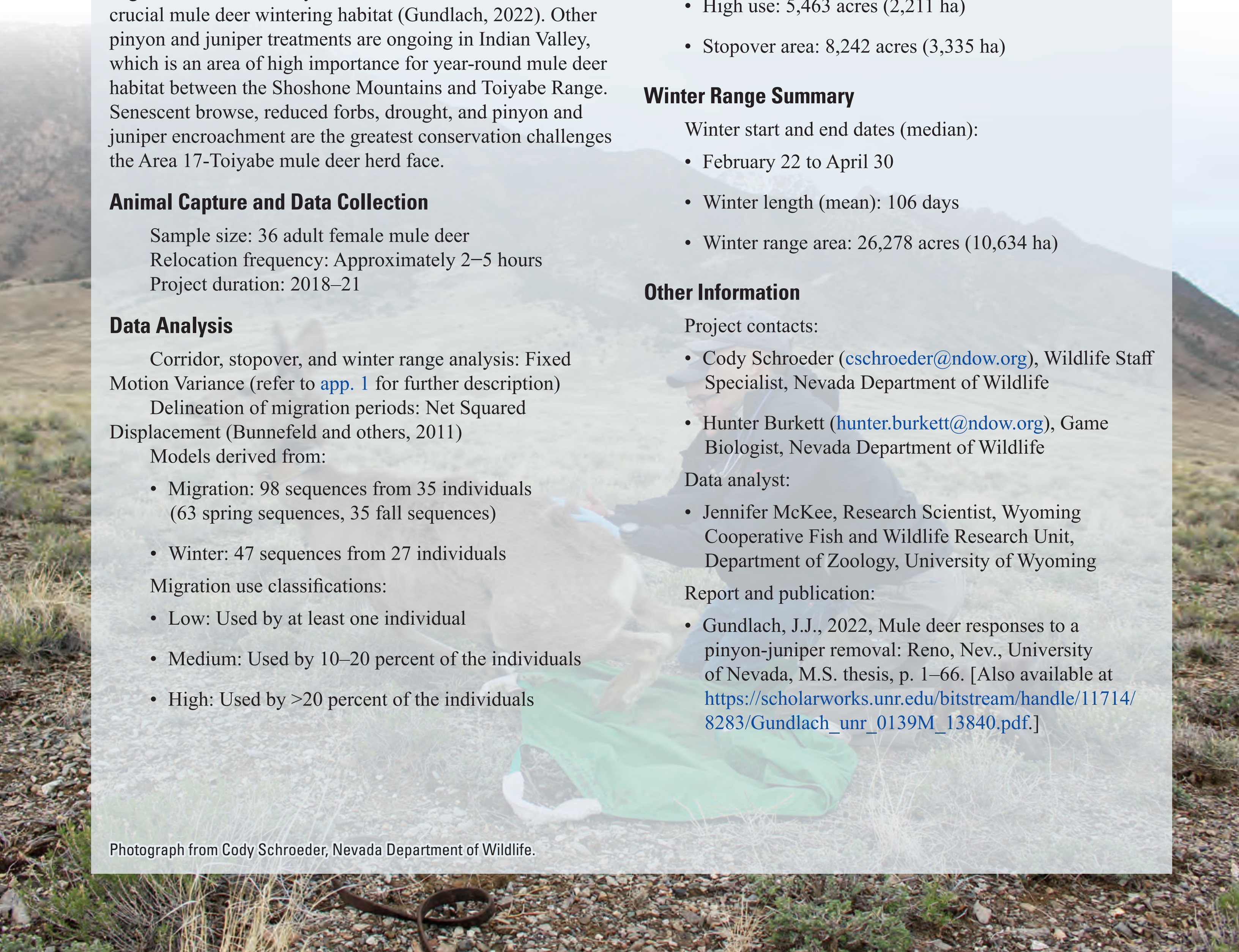
- Cody Schroeder (cschroeder@ndow.org), Wildlife Staff Specialist, Nevada Department of Wildlife
- Hunter Burkett (hunter.burkett@ndow.org), Game Biologist, Nevada Department of Wildlife

Data analyst:

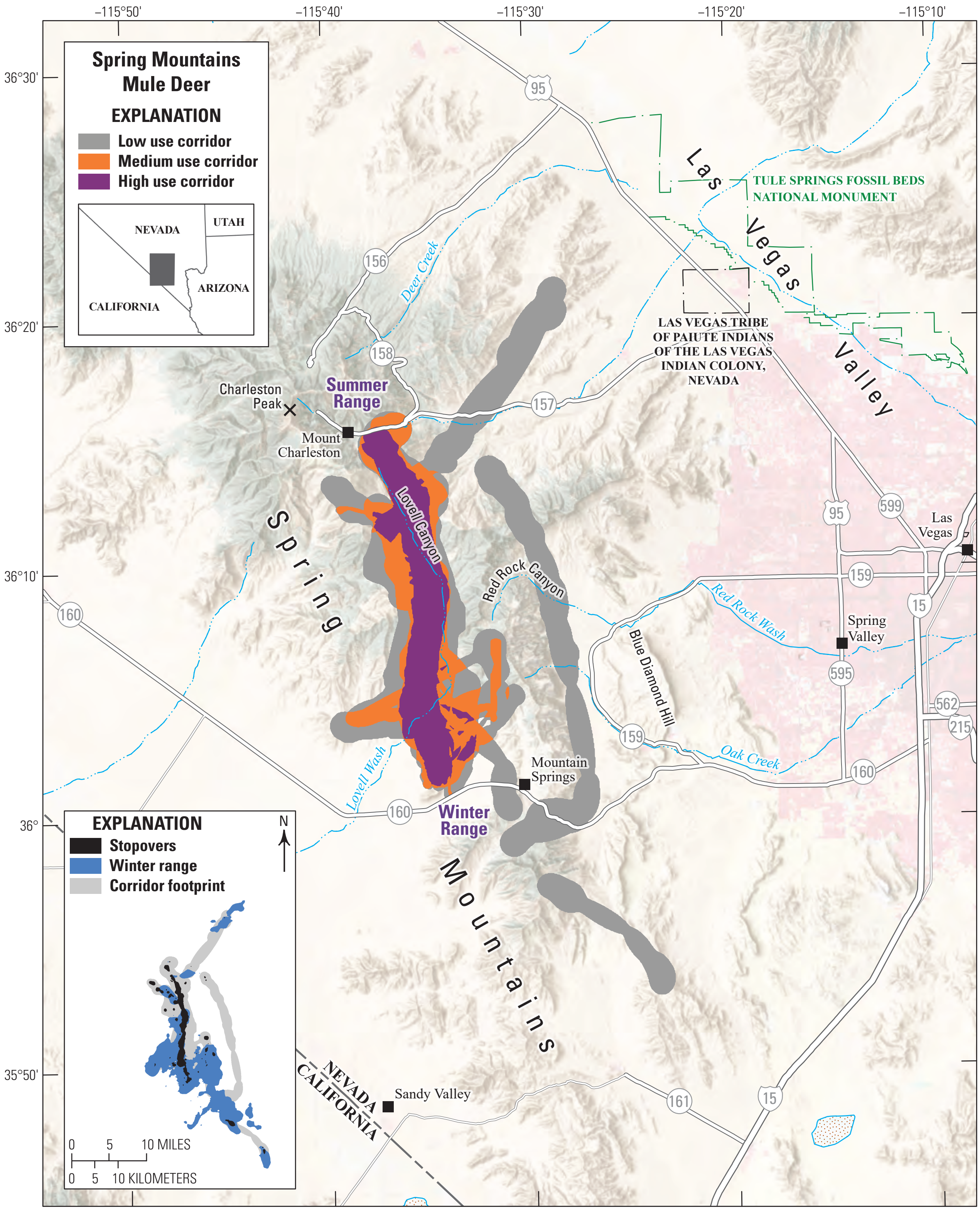
- Jennifer McKee, Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology, University of Wyoming

Report and publication:

- Gundlach, J.J., 2022, Mule deer responses to a pinyon-juniper removal: Reno, Nev., University of Nevada, M.S. thesis, p. 1–66. [Also available at https://scholarworks.unr.edu/bitstream/handle/11714/8283/Gundlach_unr_0139M_13840.pdf.]



Photograph from Cody Schroeder, Nevada Department of Wildlife.



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

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

Figure 11. Migration corridors, stopovers, summer range, and winter range of the Spring Mountains mule deer herd.

Nevada | Mule Deer

Spring Mountains Mule Deer

The Spring Mountains are critical habitat for the Spring Mountains mule deer herd in southern Nevada. The Spring Mountains west of Las Vegas, Nevada, range in elevation from low meadows at 3,000 ft (910 m) to Charleston Peak at nearly 12,000 ft (3,632 m). Lower elevations are dominated by desert scrub and shrubland, and then transition from *Yucca brevifolia* (Joshua tree) and pinyon-juniper forest at midelevations to mixed montane conifer including ponderosa pine and *Pinus longaeva* (bristlecone pine) pine at higher elevations, and sparse alpine grasses and forbs above the tree line. The migratory behavior of the Spring Mountains mule deer herd is variable and is a mix of year-round residents and short-distance elevational migrants. Lovell Canyon serves as a well-used corridor between high-elevation summer range near Mount Charleston, Nevada, and low-elevation winter range near Mountain Springs, Nevada (fig. 11). In 2020, a wildlife underpass was completed to facilitate movement across State Route 160 and reduce WVC. Most of the land in the Spring Mountains is managed by the FS and the BLM and serves as a popular, year-round recreational destination. Encroaching development, prolonged drought conditions, wildfires, feral equids, and human recreation affect the persistence of the mule deer herd in the Spring Mountains.

Animal Capture and Data Collection

Sample size: 35 adult mule deer (11 males, 24 females)
Relocation frequency: Approximately 1−13 hours
Project duration: 2015–21

Data Analysis

Corridor, stopover, and winter range analysis: Fixed Motion Variance (refer to app. 1 for further description)

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

Models derived from:

- Migration: 63 sequences from 18 individuals (37 spring sequences, 26 fall sequences)
- Winter: 61 sequences from 31 individuals

Migration use classifications:

- Low: Used by at least one individual
- Medium: Used by 10–20 percent of the individuals
- High: Used by >20 percent of the individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: April 25 to April 30
- Fall: October 10 to October 21

Number of days migrating (mean):

- Spring: 8 days
- Fall: 9 days

Migration corridor length:

- Minimum: 3.46 mi (5.57 km)
- Mean: 11.12 mi (17.89 km)
- Maximum: 18.09 mi (29.12 km)

Migration corridor area:

- Low use: 79,792 acres (32,291 ha)
- Medium use: 31,302 acres (12,667 ha)
- High use: 17,966 acres (7,271 ha)
- Stopover area: 9,373 acres (3,793 ha)

Winter Range Summary

Winter start and end dates (median):

- October 31 to April 23
- Winter length (mean): 215 days
- Winter range area: 55,425 acres (22,430 ha)

Other Information

Project contacts:

- Cody McKee (cmckee@ndow.org), Wildlife Staff Specialist, Nevada Department of Wildlife
- Cody Schroeder (cschroeder@ndow.org), Wildlife Staff Specialist, Nevada Department of Wildlife
- Erin Wood (erin.wood@ndow.org), Wildlife Biologist, Nevada Department of Wildlife

Data analyst:

- Jennifer McKee, Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology, University of Wyoming

Photograph from Dane Horowski, Nevada Department of Wildlife.

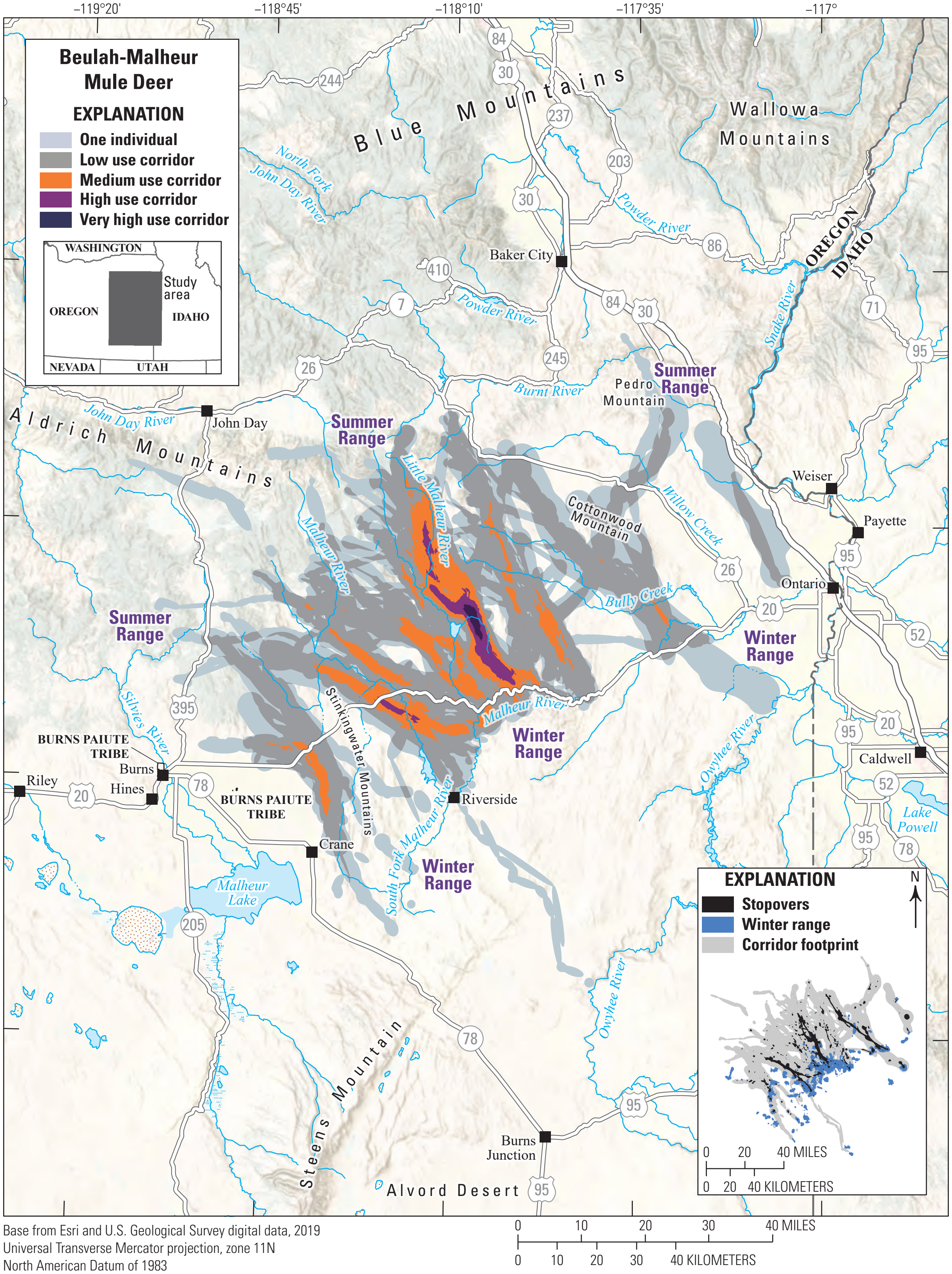


Figure 12. Migration corridors, stopovers, summer ranges, and winter ranges of the Beulah-Malheur mule deer herd.

Oregon | Mule Deer

Beulah-Malheur Mule Deer

With 204 GPS-collared mule deer, the Beulah-Malheur herd is one of the most extensively studied mule deer herds in Oregon. Beulah-Malheur mule deer primarily winter along the Malheur River and the Stinkingwater Mountains, but some mule deer winter as far south as the Owyhee River (fig. 12). Winter ranges contain *Artemisia tridentata* (big sagebrush), grassland, and encroaching *Juniperus occidentalis* (western juniper). Although spatially dispersed, much of the Beulah-Malheur mule deer herd collectively migrates northwest to reach summer ranges in the upper elevations of the surrounding national forests to the northwest. Primary summer range vegetation includes *A. t. vaseyana* (mountain big sagebrush), ponderosa pine, and western juniper with mixed-conifer forests and mountain shrub communities at higher elevations. In 2014, the Buzzard Complex fire burned approximately 398,596 acres (161,306 ha) between Riverside, Oregon, and State Route 78, allowing *Taeniatherum caput-medusae* (medusahead) and other invasive annual grasses to proliferate in areas originally lacking perennial plant cover. Mule deer cross several major roadways during migration, including U.S. Highway 20, U.S. Highway 26, and U.S. Highway 395, but Interstate 84 is functionally a complete barrier on the eastern edge. The U.S. Highway 20 transects winter ranges for migratory and resident mule deer, and the section between mileposts 135 and 258 along the Malheur River accounted for an average of 179 mule deer-vehicle collisions each year from 2010 to 2022. The Burns Paiute Tribe is working with the Oregon Department of Fish and Wildlife (ODFW) and Oregon Department of Transportation to identify wildlife passage solutions on U.S. Highway 20.

Animal Capture and Data Collection

Sample size: 204 adult female mule deer

Relocation frequency: Approximately 5–13 hours

Project duration: 2015–present (data through July 2022 analyzed for this report)

Data Analysis

Corridor, stopover, and winter range analysis: Brownian bridge movement models (Sawyer and others, 2009); corridor analysis for the 5-hour duty cycle GPS collars used Brownian Motion Variance with an 8-hour time lag; corridor analysis for the 13-hour duty cycle GPS collars used Fixed Motion Variance with a 48-hour time lag (refer to app. 1 for further description)

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

Models derived from:

- Migration: 398 sequences from 134 individuals (240 spring sequences, 158 fall sequences)
- Winter: 303 sequences from 179 individuals

Migration use classifications:

- One individual: Used by at least one individual
- Low: Used by two individuals to less than (<)5 percent of the individuals
- Medium: Used by 5–10 percent of the individuals
- High: Used by 10–20 percent of the individuals
- Very high: Used by >20 percent of the individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: April 9 to April 23
- Fall: October 31 to November 9

Number of days migrating (mean):

- Spring: 14 days
- Fall: 9 days

Migration corridor length:

- Minimum: 4.91 mi (7.90 km)
- Mean: 30.13 mi (48.49 km)
- Maximum: 65.69 mi (105.72 km)

Migration corridor area:

- One individual: 1,914,085 acres (774,603 ha)
- Low use: 1,187,439 acres (480,539 ha)
- Medium use: 227,503 acres (92,067 ha)
- High use: 35,413 acres (14,331 ha)
- Very high use: 4,219 acres (1,708 ha)
- Stopover area: 204,651 acres (82,819 ha)

Winter Range Summary

Winter start and end dates (median):

- November 9 to April 11
- Winter length (mean): 147 days
- Winter range area: 324,025 acres (131,128 ha)

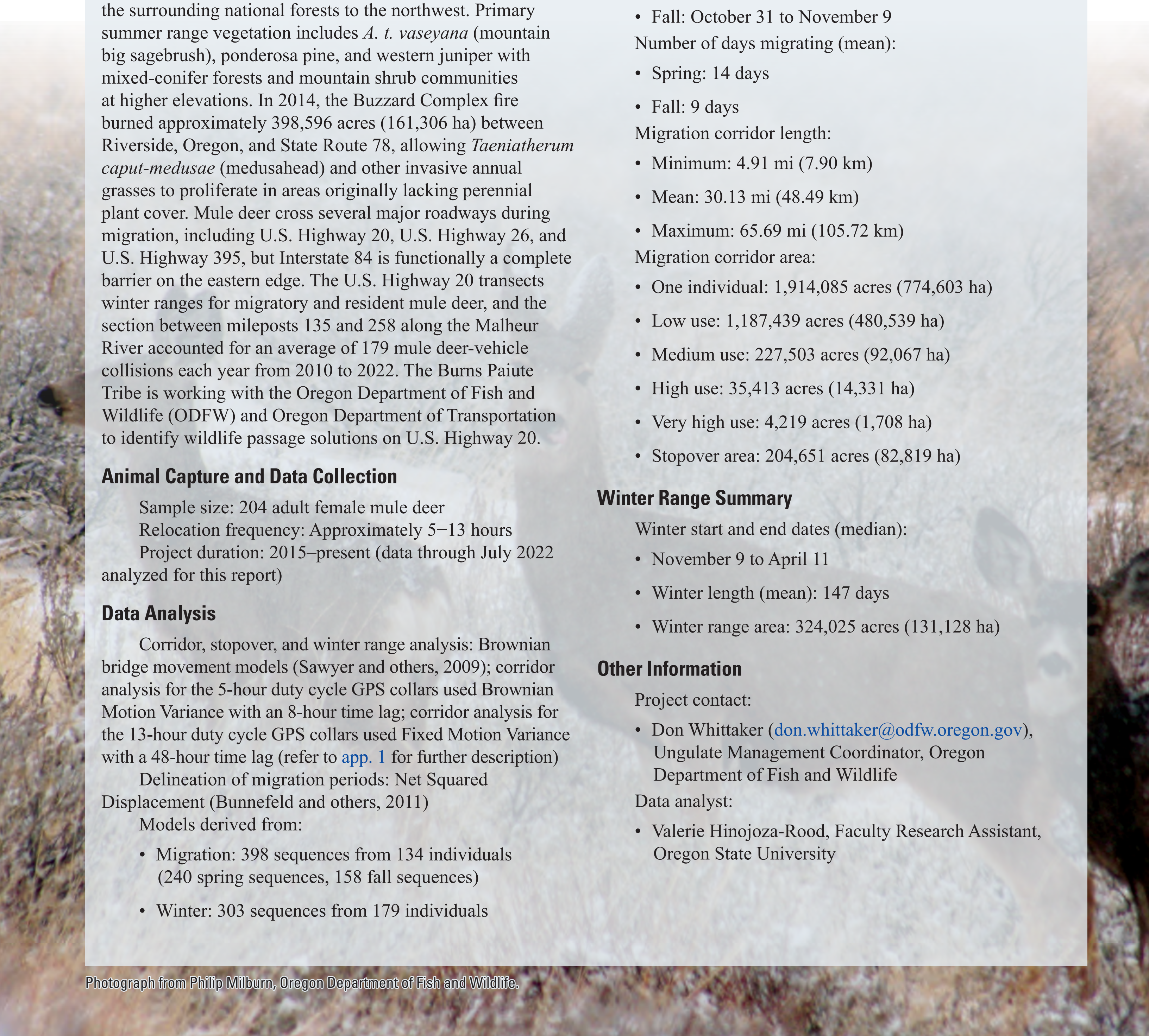
Other Information

Project contact:

- Don Whittaker (don.whittaker@odfw.oregon.gov), Ungulate Management Coordinator, Oregon Department of Fish and Wildlife

Data analyst:

- Valerie Hinojoza-Rood, Faculty Research Assistant, Oregon State University



Photograph from Philip Milburn, Oregon Department of Fish and Wildlife.

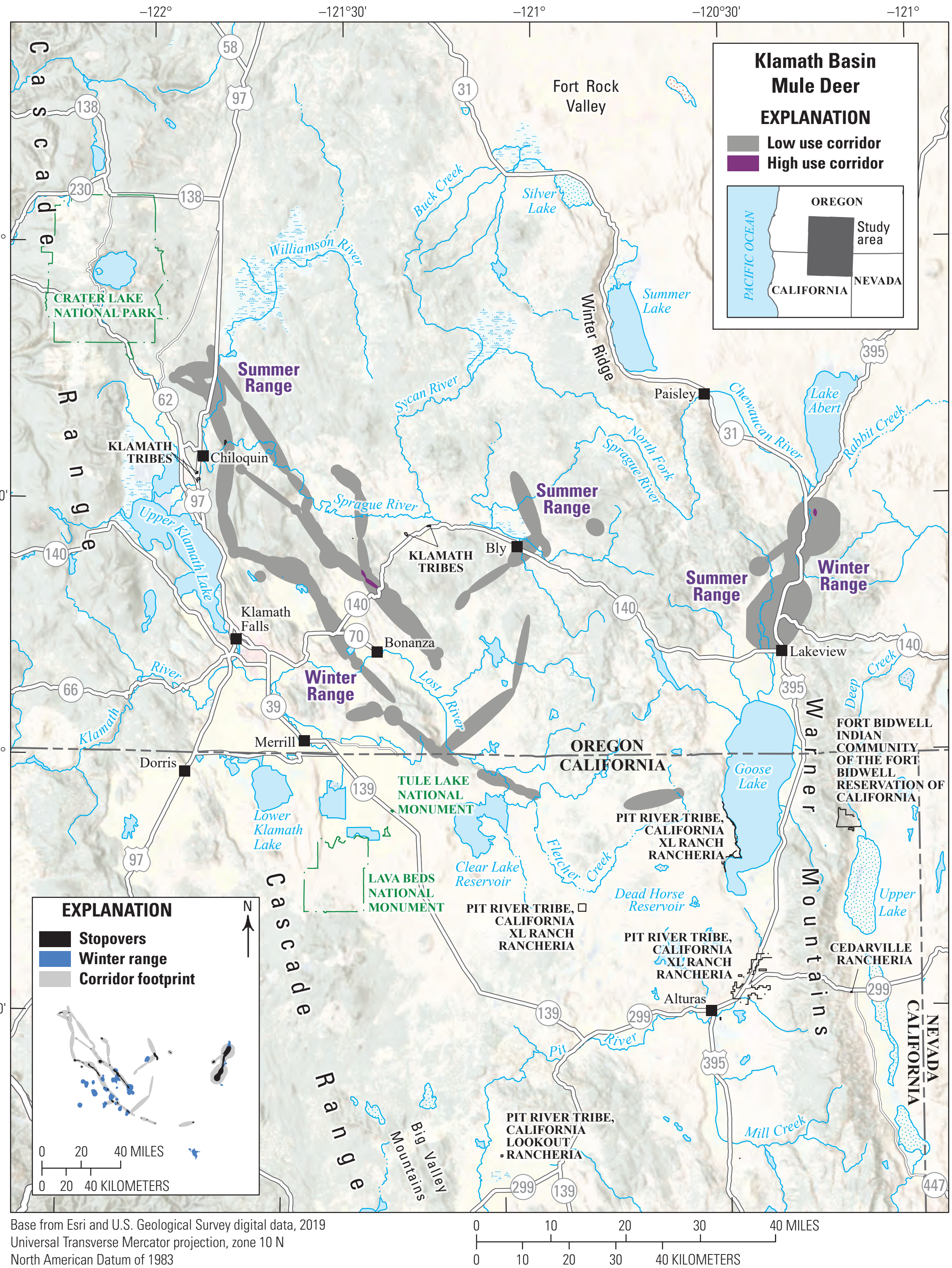


Figure 13. Migration corridors, stopovers, summer ranges, and winter ranges of the Klamath Basin mule deer herd.

Oregon | Mule Deer

Klamath Basin Mule Deer

The Klamath Basin mule deer herd contains an estimated 10,775 mule deer and is a mix of resident and migratory animals. Most winter ranges are adjacent to the California border near Bly, Oregon, and Lost River, California, in areas with western juniper, low shrublands, and early shrub-tree habitat (fig. 13). In spring, these mule deer either migrate northwest to regional national forest lands or northeast past Oregon Route 140. Summer ranges contain ponderosa pine, mixed-conifer forests, and early shrub-tree habitat along with alfalfa and other agricultural crops. Notably, one GPS-collared mule deer migrated southeast into California near Goose Lake in May 2019 and spent a year near Dead Horse Reservoir before returning to Oregon in November 2020. Out of four mule deer GPS collared during a single capture, one migrated from Lake Abert to Lakeview, Oregon, along U.S. Highway 395 in spring. This stretch of U.S. Highway 395 had an average annual daily traffic (AADT) value of 1,002 vehicles in 2018. Several other mule deer also crossed sections of U.S. Highway 97, an even busier road with an AADT value of 5,298 vehicles in 2018. From 2010 to 2022, Oregon Department of Transportation recorded an average of 65.7 mule deer-vehicle collisions per year along a 44.8-mi (72.1-km) section of U.S. Highway 97 north of Klamath Falls, Oregon. Klamath Basin mule deer numbers are slowly declining, in part because of reduced summer forage quality (Peek and others, 2002). Forest fire suppression beginning in the 1920s increased canopy closure in the summer range, reducing preferred understory vegetation such as *Purshia tridentata* (antelope bitterbrush) and *Ceanothus velutinus* (snowbrush ceanothus). Without sufficient high-quality forage during drought years, mule deer become more reliant on agricultural fields near Klamath Falls as a dependable water source. Canopy closure also contributed to the severity of the 2021 Bootleg fire, the third largest recorded fire in Oregon, which burned 413,765 acres (167,445 ha) north of the Sprague River.

Animal Capture and Data Collection

Sample size: 34 adult female mule deer

Relocation frequency: Approximately 5−13 hours

Project duration: 2018–present (data through July 2022 analyzed for this report)

Data Analysis

Corridor, stopover, and winter range analysis: Brownian bridge movement models (Sawyer and others, 2009); corridor analysis for the 5-hour duty cycle GPS collars used Brownian Motion Variance with an 8-hour time lag; corridor analysis for the 13-hour duty cycle GPS collars used Fixed Motion Variance with a 48-hour time lag (refer to app. 1 for further description)

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

Models derived from:

- Migration: 24 sequences from 11 individuals (14 spring sequences, 10 fall sequences)
- Winter: 44 sequences from 27 individuals

Migration use classifications:

- Low: Used by at least one individual to 20 percent of the individuals
- High: Used by >20 percent of the individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: April 18 to May 1
- Fall: November 17 to November 28

Number of days migrating (mean):

- Spring: 11 days
- Fall: 9 days

Migration corridor length:

- Minimum: 11.14 mi (17.92 km)
- Mean: 30.97 mi (49.85 km)
- Maximum: 60.25 mi (96.96 km)

Migration corridor area:

- Low use: 339,464 acres (137,376 ha)
- High use: 1,248 acres (505 ha)
- Stopover area: 45,270 acres (18,320 ha)

Winter Range Summary

Winter start and end dates (median):

- December 7 to April 15
- Winter length (mean): 139 days
- Winter range area: 88,154 acres (35,675 ha)

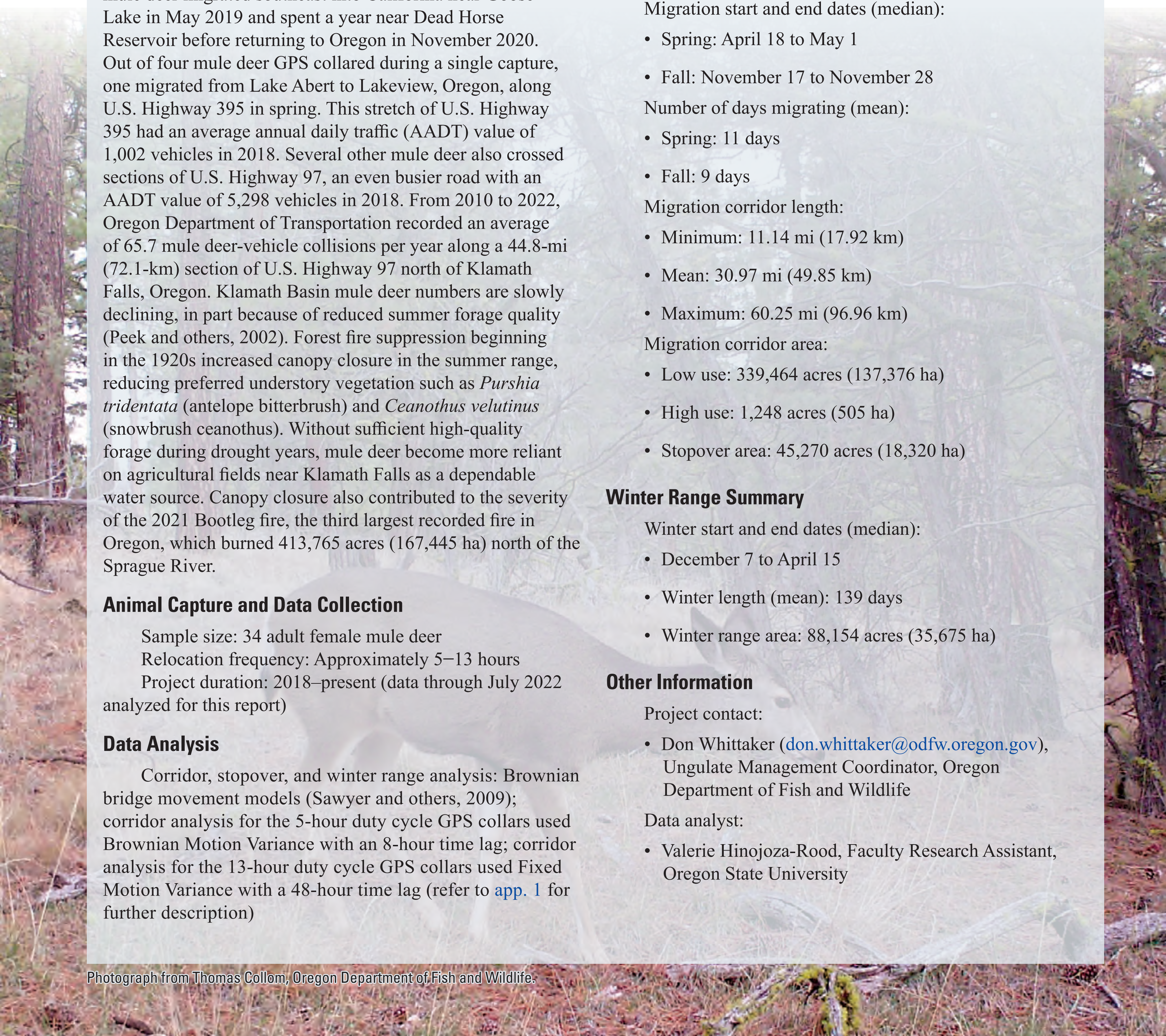
Other Information

Project contact:

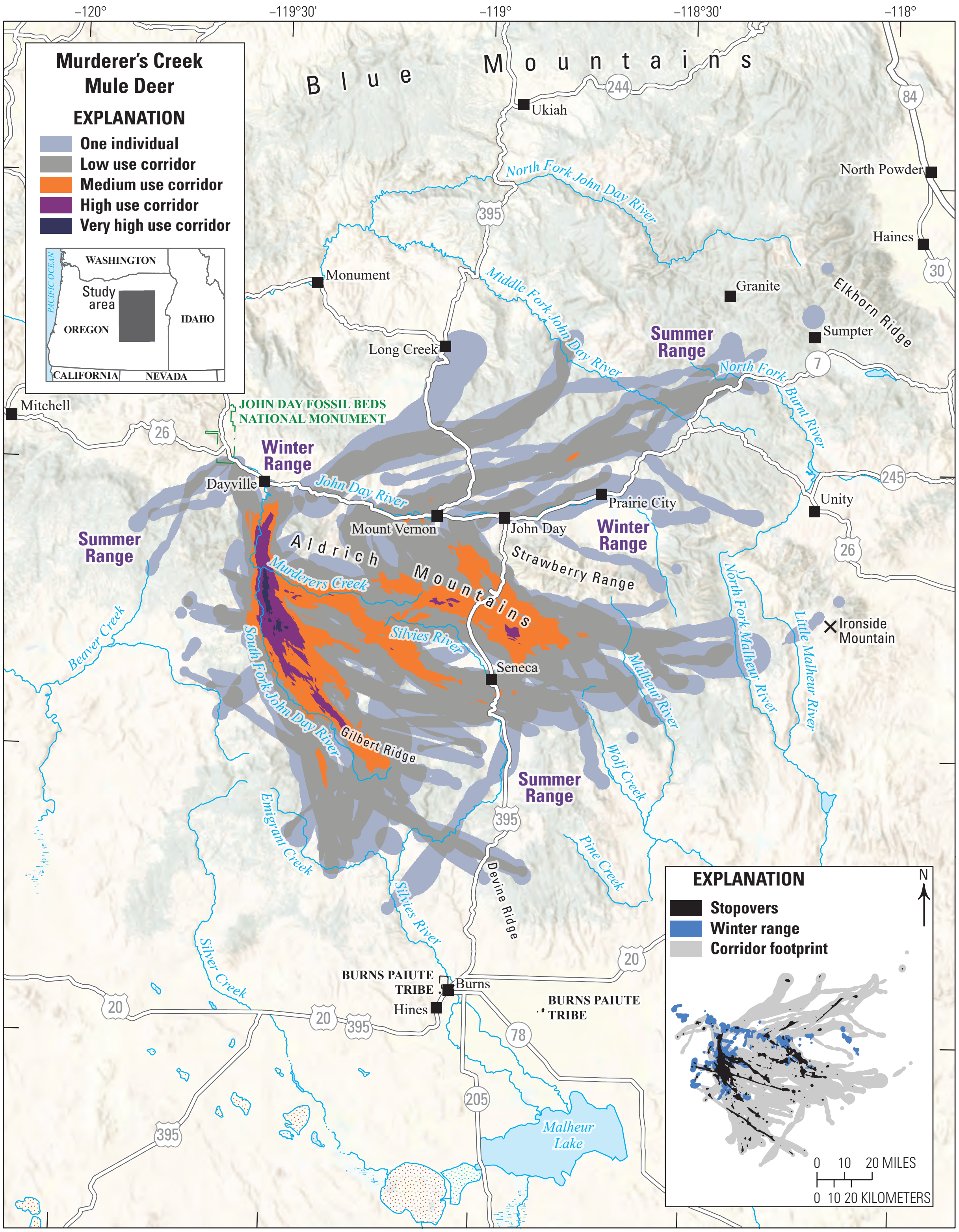
- Don Whittaker (don.whittaker@odfw.oregon.gov), Ungulate Management Coordinator, Oregon Department of Fish and Wildlife

Data analyst:

- Valerie Hinojoza-Rood, Faculty Research Assistant, Oregon State University



Photograph from Thomas Collom, Oregon Department of Fish and Wildlife.



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Universal Transverse Mercator, zone 11 north
North American Datum of 1983

Figure 14. Migration corridors, stopovers, summer ranges, and winter ranges of the Murderer's Creek mule deer herd.

Oregon | Mule Deer

Murderer's Creek Mule Deer

The Murderer's Creek mule deer herd winters south of U.S. Highway 26 in river valleys near Murderer's Creek and the South Fork John Day River (fig. 14). The herd's winter ranges at lower elevations are characterized by western juniper, big sagebrush, Columbia Basin grassland communities, and invasive medusahead and other nonnative grasses. In the spring, mule deer mainly migrate southeast to summer ranges distributed throughout Gilbert Ridge and the Aldrich Mountains, and some deer migrate as far south as Devine Ridge and east to Ironside Mountain. Summer ranges in these areas contain mixed-conifer forests, ponderosa pine, and low sagebrush communities. A smaller portion of this herd migrates northeast in the spring, crossing U.S. Highway 26 to summer near Long Creek, the Blue Mountains, and Elkhorn Ridge; these areas contain big sagebrush, *Populus tremuloides* (quaking aspen), ponderosa pine, and mixed-conifer forests.

Threats that may affect the Murderer's Creek mule deer herd include feral horses, habitat degradation, and wildfires. In areas of low-quality browse, Murderer's Creek mule deer that migrate or reside south of U.S. Highway 26 can compete with feral horses, particularly during drought years. The Murderer's Creek Herd Management Area (HMA) currently contains 329 feral horses (BLM, 2023), significantly more than the maximum appropriate management level of 140 horses (FS, 2009). In 2010, the Murderer's Creek Wildlife Management Unit (WMU), which overlaps the Murderer's Creek HMA, was included in the "Oregon Mule Deer Initiative" to improve conditions for mule deer, primarily through habitat restoration (ODFW, 2011). Since 2010, ODFW, FS, and the Natural Resources Conservation Service have treated 17,295 acres (6,999 ha) for western juniper removal and reseeded 10,016 acres (4,053 ha) for native shrubs and grasses, in addition to temporarily closing 128 mi^2 (332 km^2) of road in the Flagtail Travel Management Area during mule deer hunting season (ODFW, 2015, 2020). In 2015, the Canyon Creek Complex fire burned 110,261 acres (44,621 ha) of the Aldrich Mountains, reducing canopy closure and further improving habitat in summer ranges. The Murderer's Creek mule deer herd is now stable, and in 2021, had an estimated 5,568 mule deer (ODFW, 2021).

Animal Capture and Data Collection

Sample size: 152 adult female mule deer

Relocation frequency: Approximately 5−13 hours

Project duration: 2015–present (data through July 2022 analyzed for this report)

Data Analysis

Corridor, stopover, and winter range analysis: Brownian bridge movement models (Sawyer and others, 2009); corridor analysis for the 5-hour duty cycle GPS collars used Brownian Motion Variance with an 8-hour time lag; corridor analysis for the 13-hour duty cycle GPS collars used Fixed Motion Variance with a 48-hour time lag (refer to app. 1 for further description)

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

Models derived from:

- Migration: 274 sequences from 101 individuals (168 spring sequences, 106 fall sequences)
- Winter: 185 sequences from 116 individuals

Migration use classifications:

- One individual: Used by at least one individual
- Low: Used by two individuals to <5 percent of the individuals
- Medium: Used by 5–10 percent of the individuals
- High: Used by 10–20 percent of the individuals
- Very high: Used by >20 percent of the individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: April 21 to May 1
- Fall: October 10 to October 21

Number of days migrating (mean):

- Spring: 10 days
- Fall: 12 days

Migration corridor length:

- Minimum: 5.14 mi (8.28 km)
- Mean: 29.40 mi (47.31 km)
- Maximum: 72.35 mi (116.44 km)

Migration corridor area:

- One individual: 1,488,395 acres (602,332 ha)
- Low use: 905,152 acres (366,302 ha)
- Medium use: 200,122 acres (80,987 ha)
- High use: 37,437 acres (15,150 ha)
- Very high use: 2,938 acres (1,189 ha)
- Stopover area: 159,494 acres (64,545 ha)

Winter Range Summary

Winter start and end dates (median):

- October 24 to April 22
- Winter length (mean): 166 days
- Winter range area: 185,409 acres (75,032 ha)

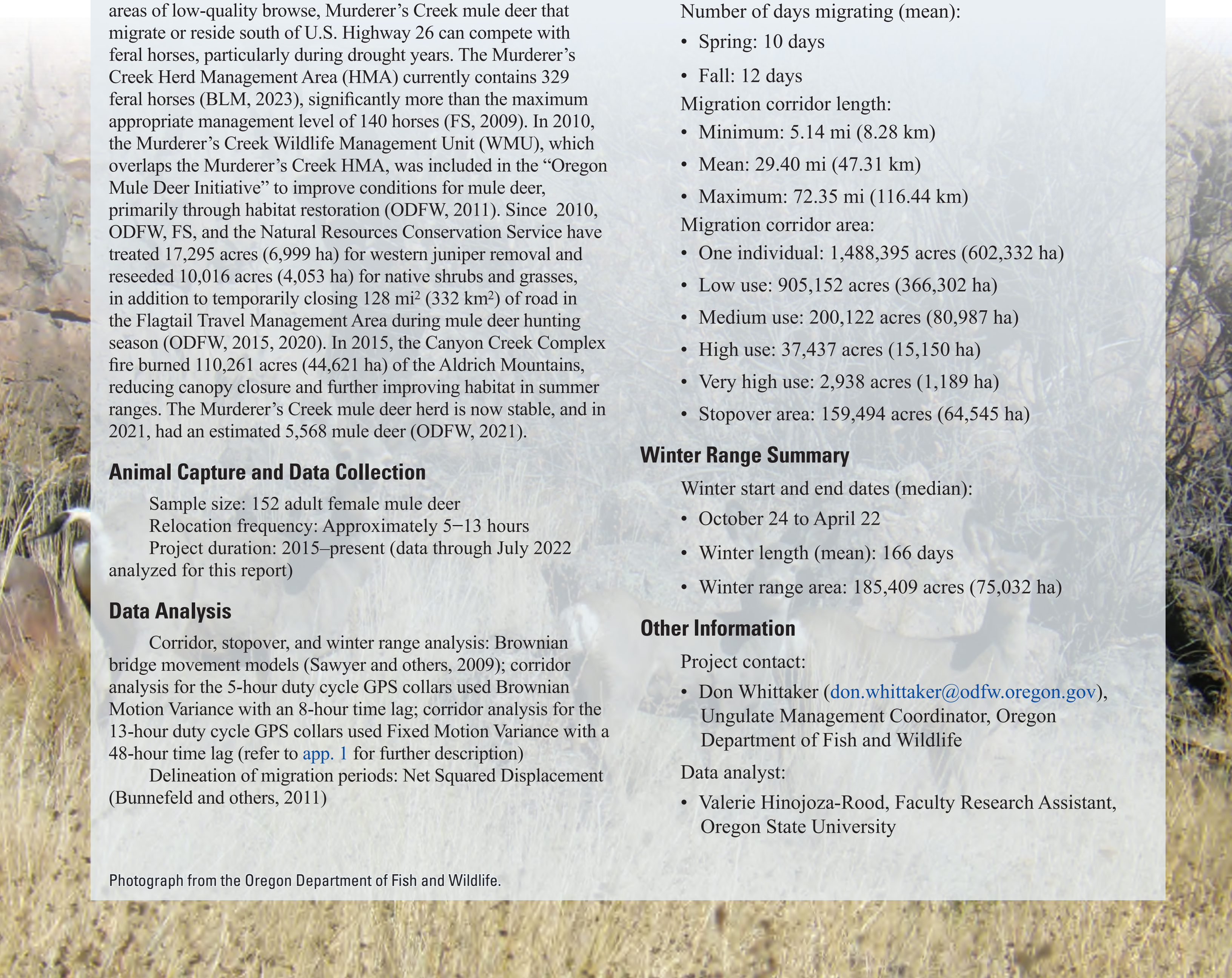
Other Information

Project contact:

- Don Whittaker (don.whittaker@odfw.oregon.gov), Ungulate Management Coordinator, Oregon Department of Fish and Wildlife

Data analyst:

- Valerie Hinojoza-Rood, Faculty Research Assistant, Oregon State University



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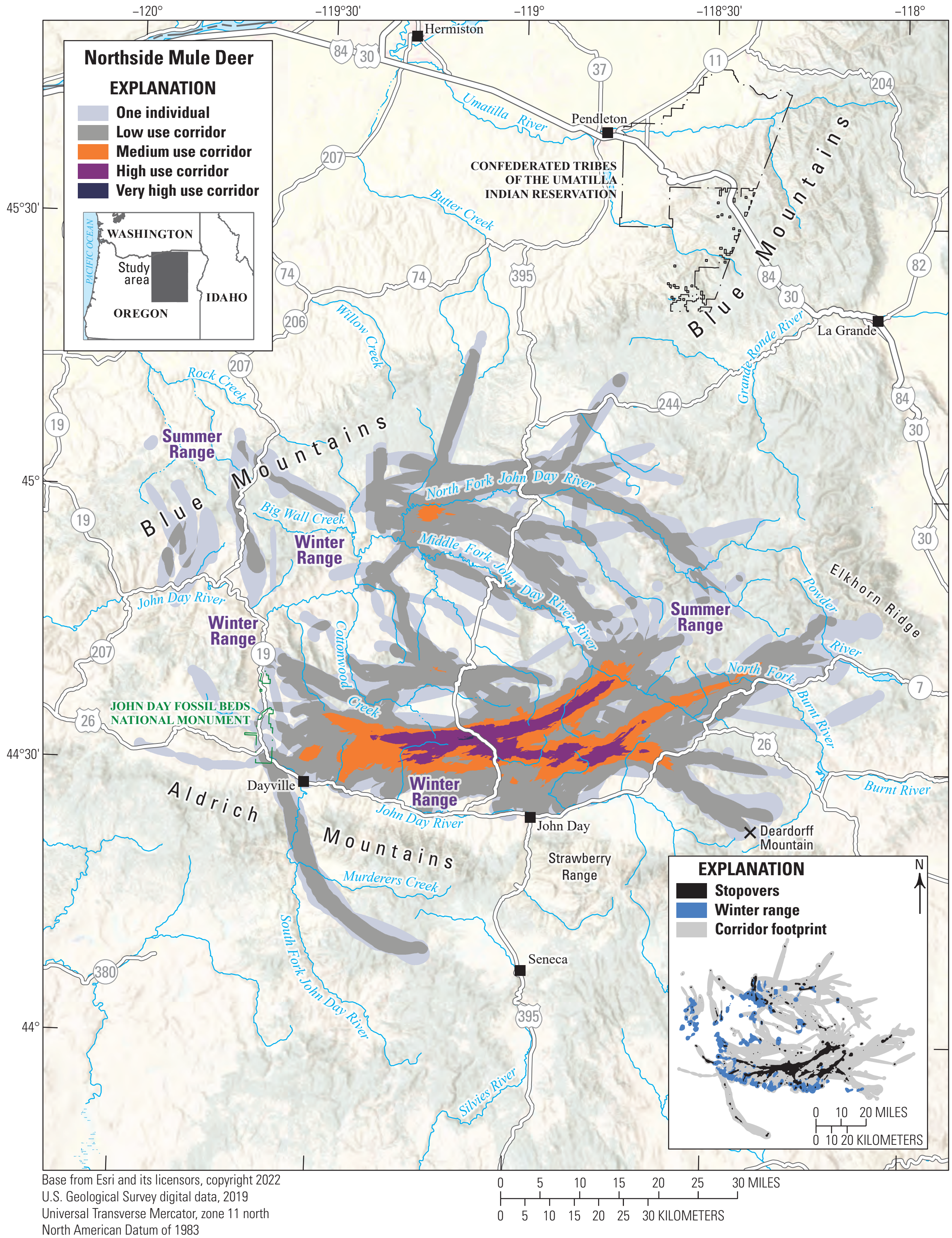


Figure 15. Migration corridors, stopovers, summer ranges, and winter ranges of the Northside mule deer herd.

Oregon | Mule Deer

Northside Mule Deer

The winter ranges of the Northside mule deer herd can be broadly separated into northern and southern subgroups. Most of the southern subgroup winters at low elevations near the John Day River in areas dominated by big sagebrush, western juniper, and Columbia Basin grassland communities. The northern subgroup is more spatially dispersed and winters by Cottonwood Creek, the North Fork John Day River, and the Middle Fork John Day River in ranges containing more conifer forest (fig. 15). Both subgroups summer in the same general area, migrating either northeast or southeast to reach areas containing mixed-conifer, *Picea* spp. (spruce), ponderosa pine, and western juniper forests that have scattered Columbia Basin grassland communities on the Blue Mountains and Elkhorn Ridge. Some mule deer west of the North Fork John Day River migrate north to reach summer ranges near Rock Creek. Five mule deer migrated south, crossing the section of U.S. Highway 26 dividing the Northside and Murderer's Creek mule deer herds. Because U.S. Highway 26 also separates resident mule deer from agricultural fields with reliable water sources, mule deer-vehicle collisions are common year round, and this section experienced an average of 106 mule deer-vehicle collisions per year from 2016 to 2022. In 2010, the Heppner WMU, which is used for livestock grazing and contains multiple mule deer winter ranges, was included in the "Oregon Mule Deer Initiative" (ODFW, 2015, 2020). Since 2010, ODFW, FS, and the Natural Resources Conservation Service have removed 10,256.7 acres (4,150.7 ha) of invasive flora, reseeded 7,405.3 acres (2,996.8 ha) with native shrubs and grassland, and completed 48 water development projects to improve mule deer habitat.

Animal Capture and Data Collection

Sample size: 203 adult female mule deer

Relocation frequency: Approximately 5−13 hours

Project duration: 2015–present (data through July 2022 analyzed for this report)

Data Analysis

Migration and stopover analysis: Brownian bridge movement models (Sawyer and others, 2009); corridor analysis for the 5-hour duty cycle GPS collars used Brownian Motion Variance with an 8-hour time lag; corridor analysis for the 13-hour duty cycle GPS collars used Fixed Motion Variance with a 48-hour time lag (refer to app. 1 for further description)

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

Models derived from:

- Migration: 360 sequences from 144 individuals (226 spring sequences, 134 fall sequences)
- Winter: 239 sequences from 114 individuals

Migration use classifications:

- One individual: Used by at least one individual
- Low: Used by two individuals to <5 percent of the individuals
- Medium: Used by 5–10 percent of the individuals
- High: Used by 10–20 percent of the individuals
- Very high: Used by >20 percent of the individuals

Migration and Stopover Summary

Migration start and end date (median):

- Spring: April 19 to May 1
- Fall: October 22 to November 1

Number of days migrating (mean):

- Spring: 10 days
- Fall: 8 days

Migration length:

- Minimum: 6.14 mi (9.88 km)
- Mean: 29.86 mi (48.05 km)
- Maximum: 65.63 mi (105.62 km)

Migration corridor area:

- One individual: 1,493,023 acres (604,205 ha)
- Low use: 934,003 acres (377,977 ha)
- Medium use: 183,951 acres (74,442 ha)
- High use: 60,943 acres (24,663 ha)
- Very high use: 300 acres (121 ha)
- Stopover area: 160,722 acres (65,042 ha)

Winter Range Summary

Winter start and end dates (median):

- November 2 to April 24
- Winter length (mean): 164 days
- Winter range area: 232,359 acres (94,032 ha)

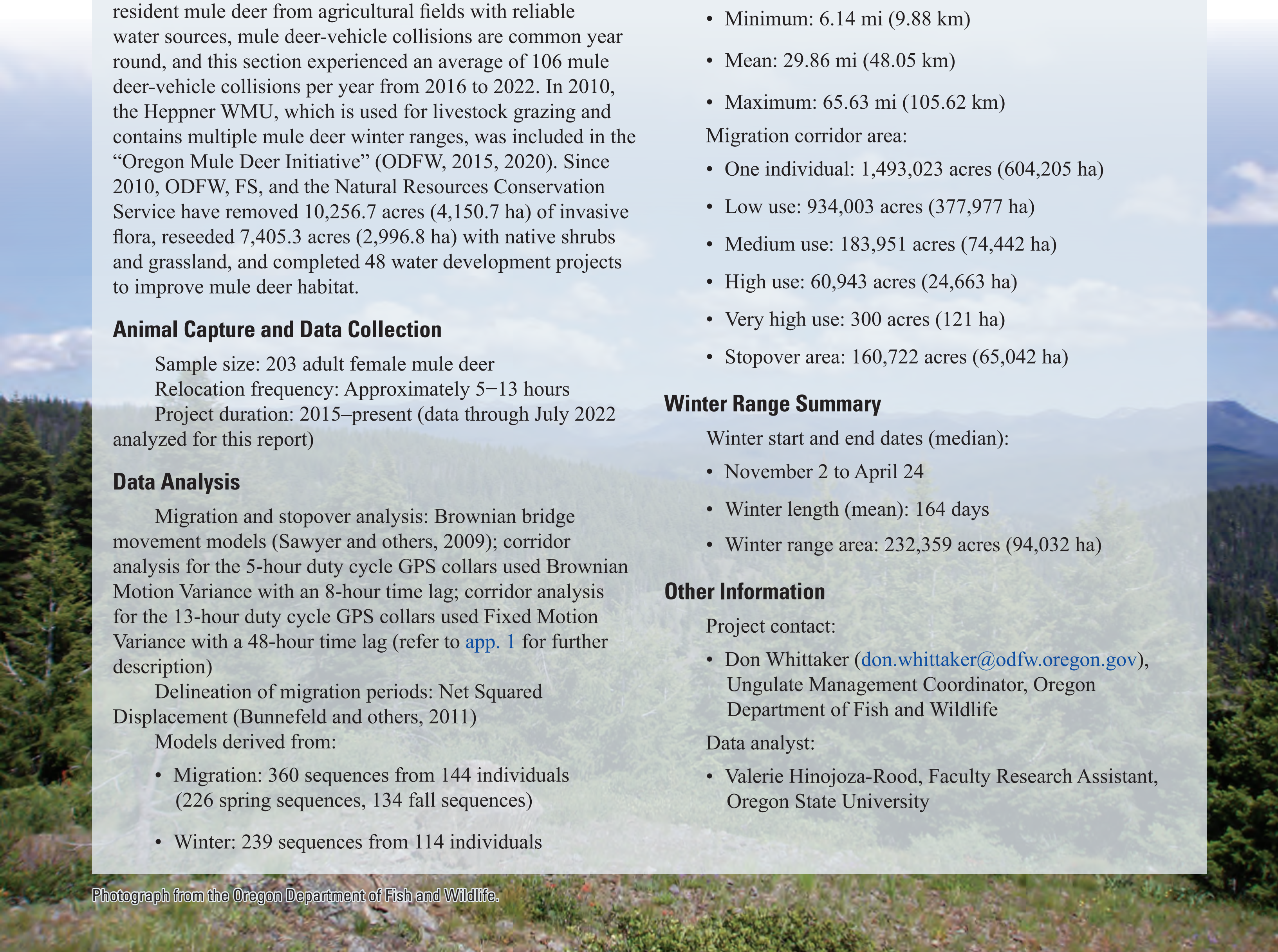
Other Information

Project contact:

- Don Whittaker (don.whittaker@odfw.oregon.gov), Ungulate Management Coordinator, Oregon Department of Fish and Wildlife

Data analyst:

- Valerie Hinojoza-Rood, Faculty Research Assistant, Oregon State University



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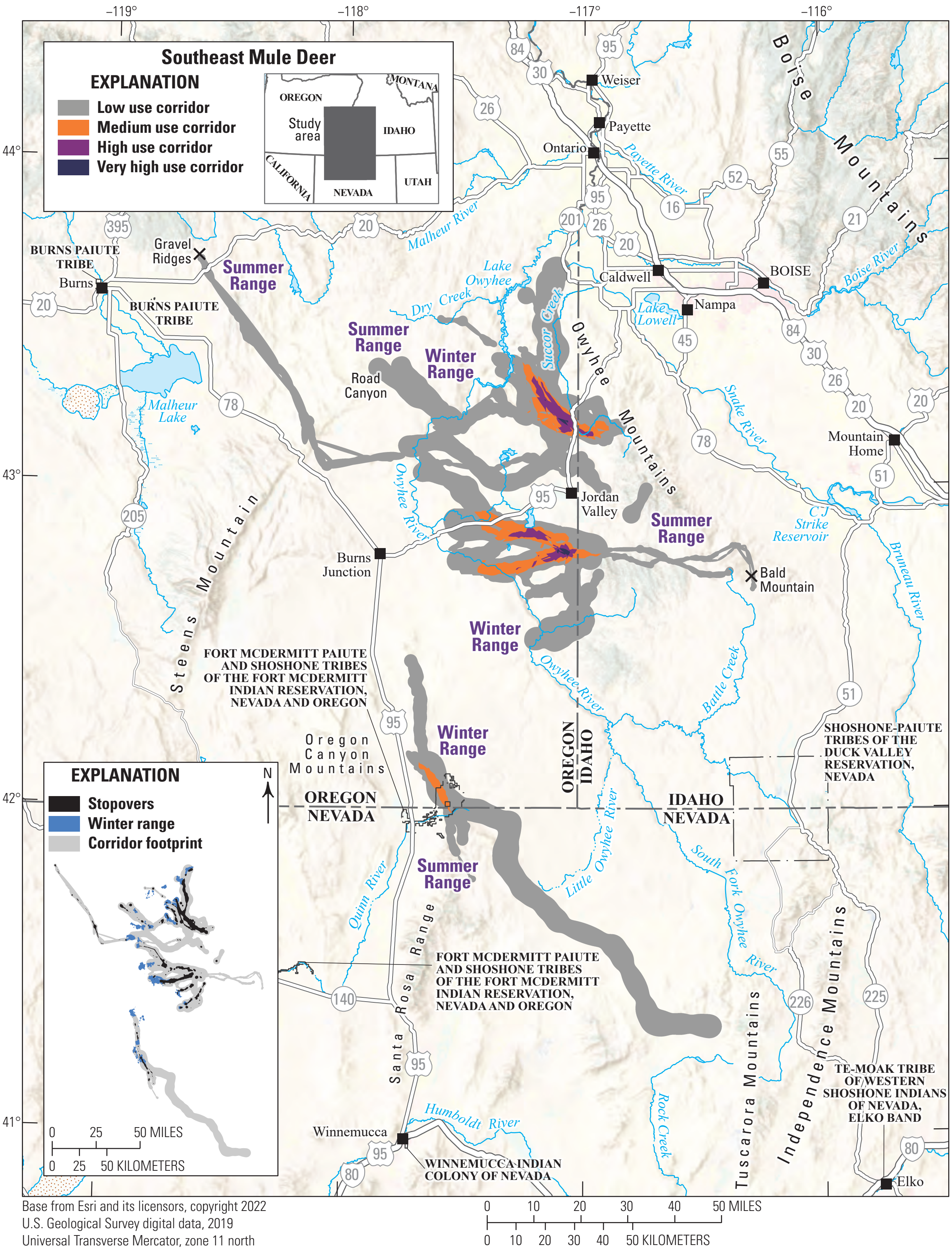

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Figure 16. Migration corridors, stopovers, summer ranges, and winter ranges of the Southeast mule deer herd.

Oregon | Mule Deer

Southeast Mule Deer

Most of the Southeast mule deer herd winters along the Owyhee River in areas containing sagebrush communities and Columbia Basin grassland communities mixed with nonnative annual grasslands. These mule deer either migrate west to summer ranges on Road Canyon and Gravel Ridges or east to the Owyhee Mountains along the Idaho border. One mule deer migrated 38.3 mi (61.6 km) into Idaho, as far as Bald Mountain (fig. 16). Summer ranges contain shrubland, Columbia Basin grassland communities, western juniper, and evergreen forests. In 2014, the Buzzard Complex fire burned 398,596 acres (161,306 ha), including Road Canyon, allowing medusahead and other nonnative grasses to invade areas with originally low perennial plant abundance. Five mule deer wintered separately near U.S. Highway 95, in areas containing higher percentages of western juniper. In the spring, deer migrated southeast into Nevada to summer on the Santa Rosa Range and one mule deer migrated to the Tuscarora Mountains. Of the Southeast mule deer tracked for at least 100 days, 82 percent migrated seasonally. Several mule deer migrated to summer ranges in different States, which complicated population management. The Southeast mule deer herd faces several challenges, including highways and the low abundance of preferred browse. The northeastern section of U.S. Highway 95 had an AADT value of 2,007 vehicles in 2018 and intersects multiple migration corridors; mule deer commonly cross the highway near Succor Creek. In summer, Southeast mule deer spend more time in riparian zones and may compete with livestock and elk in the Owyhee Mountains for high-quality forage during drought years.

Animal Capture and Data Collection

Sample size: 50 adult female mule deer

Relocation frequency: Approximately 5–13 hours

Project duration: 2018–present (data through July 2022 analyzed for this report)

Data Analysis

Corridor, stopover, and winter range analysis: Brownian bridge movement models (Sawyer and others, 2009); corridor analysis for the 5-hour duty cycle GPS collars used Brownian Motion Variance with an 8-hour time lag; corridor analysis for the 13-hour duty cycle GPS collars used Fixed Motion Variance with a 48-hour time lag (refer to app. 1 for further description)

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

Models derived from:

- Migration: 140 sequences from 37 individuals (84 spring sequences, 56 fall sequences)
- Winter: 63 sequences from 34 individuals

Migration use classifications:

- Low: Used by at least one individual
- Medium: Used by 10–15 percent of the individuals
- High: Used by 15–20 percent of the individuals
- Very high: Used by >20 percent of the individuals

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: April 7 to April 14
- Fall: October 29 to November 12

Number of days migrating (mean):

- Spring: 11 days
- Fall: 10 days

Migration length:

- Minimum: 5.21 mi (8.38 km)
- Mean: 25.63 mi (41.24 km)
- Maximum: 83.02 mi (133.60 km)

Migration corridor area:

- Low use: 1,476,242 acres (597,414 ha)
- Medium use: 144,640 acres (58,534 ha)
- High use: 38,465 acres (15,566 ha)
- Very high use: 2,246 acres (909 ha)
- Stopover area: 174,880 acres (70,771 ha)

Winter Range Summary

Winter start and end dates (median):

- November 15 to April 6
- Winter length (mean): 143 days
- Winter range area: 152,563 acres (61,740 ha)

Other Information

Project contact:

- Don Whittaker (don.whittaker@odfw.oregon.gov), Ungulate Management Coordinator, Oregon Department of Fish and Wildlife

Data analyst:

- Valerie Hinojoza-Rood, Faculty Research Assistant, Oregon State University

Photograph from the Oregon Department of Fish and Wildlife-Malheur District.

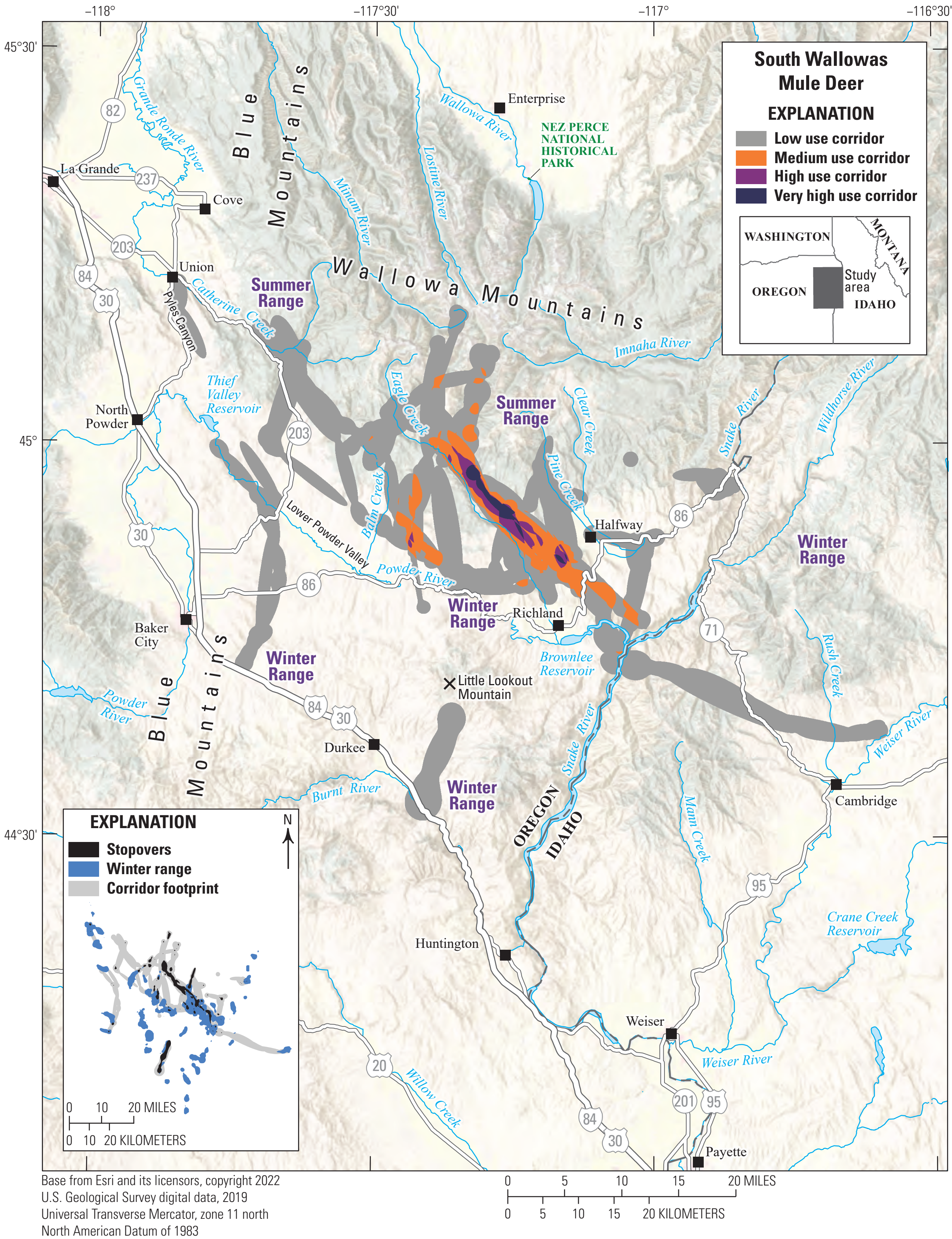


Figure 17. Migration corridors, stopovers, summer ranges, and winter ranges of the South Wallowas mule deer herd.

Oregon | Mule Deer

South Wallowas Mule Deer

The South Wallowas mule deer herd's winter ranges are dispersed in areas of low elevation near the Oregon-Idaho border (fig. 17). During spring, mule deer wintering north of Powder River and Pyles Canyon migrate to Catherine Creek and the Wallowa Mountains in the Wallowa-Whitman National Forest. Interstate 84 is an effective barrier to southern movement for the South Wallowas herd. Mule deer wintering in areas near Interstate 84 are largely residents and only two GPS-collared mule deer migrated to Little Lookout Mountain and Thief Valley Reservoir. Other mule deer reside along the Snake River, which forms the Oregon-Idaho border. One mule deer crossed Snake River south of the Powder River headwaters, migrating 24.46 mi (39.36 km) to Weiser River north of Cambridge, Idaho. The herd's winter range primarily consists of sagebrush communities and Columbia Basin grassland communities, and summer ranges contain big sagebrush, spruce, quaking aspen, and mixed-conifer forests. Mule deer tend to avoid the lowest elevation areas near Lower Powder Valley, Richland, and Durkee, Oregon, and instead prefer to winter at an average elevation of 3,435 ft (1,047 m) and summer at an average elevation of 5,185 ft (1,580 m). The South Wallowas herd traverses the Keating WMU, which was included in the 2015 "Oregon Mule Deer Initiative" (ODFW, 2020). Since 2015, ODFW, FS, BLM, and the Natural Resources Conservation Service have removed 159 acres (64 ha) of western juniper, reseeded 203 acres (82 ha) with native shrubs and grasses, and thinned 265 acres (107 ha) of timber stands. The effects of ODFW habitat improvements were reduced in 2017 when January snow depth exceeded 30 inches (76 centimeters) in mule deer winter ranges and average overwinter fawn survival dropped to 24 percent; however, fawn survival has since returned to 77 percent in 2018–21 (ODFW, 2021).

Animal Capture and Data Collection

Sample size: 73 adult female mule deer
Relocation frequency: Approximately 5–13 hours
Project duration: 2016–20

Data Analysis

Migration and stopover analysis: Brownian bridge movement models (Sawyer and others, 2009); corridor analysis for the 5-hour duty cycle GPS collars used Brownian Motion Variance with an 8-hour time lag; corridor analysis for the 13-hour duty cycle GPS collars used Fixed Motion Variance with a 48-hour time lag (refer to app. 1 for further description)

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

Models derived from:

- Migration: 64 sequences from 27 individuals (33 spring sequences, 31 fall sequences)
- Winter: 86 sequences from 56 individuals

Migration use classifications:

- Low: Used by at least one individual
- Medium: Used by 10–15 percent of the individuals
- High: Used by 15–20 percent of the individuals
- Very high: Used by >20 percent of the individuals

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: April 17 to April 24
- Fall: October 31 to November 7

Number of days migrating (mean):

- Spring: 9 days
- Fall: 7 days

Migration length:

- Minimum: 3.40 mi (5.48 km)
- Mean: 13.33 mi (21.45 km)
- Maximum: 27.80 mi (44.74 km)

Migration corridor area:

- Low use: 297,796 acres (120,514 ha)
- Medium use: 37,998 acres (15,377 ha)
- High use: 9,342 acres (3,781 ha)
- Very high use: 3,235 acres (1,309 ha)
- Stopover area: 35,898 acres (14,528 ha)

Winter Range Summary

Winter start and end dates (median):

- November 19 to April 22
- Winter length (mean): 148 days
- Winter range area: 180,219 acres (72,932 ha)

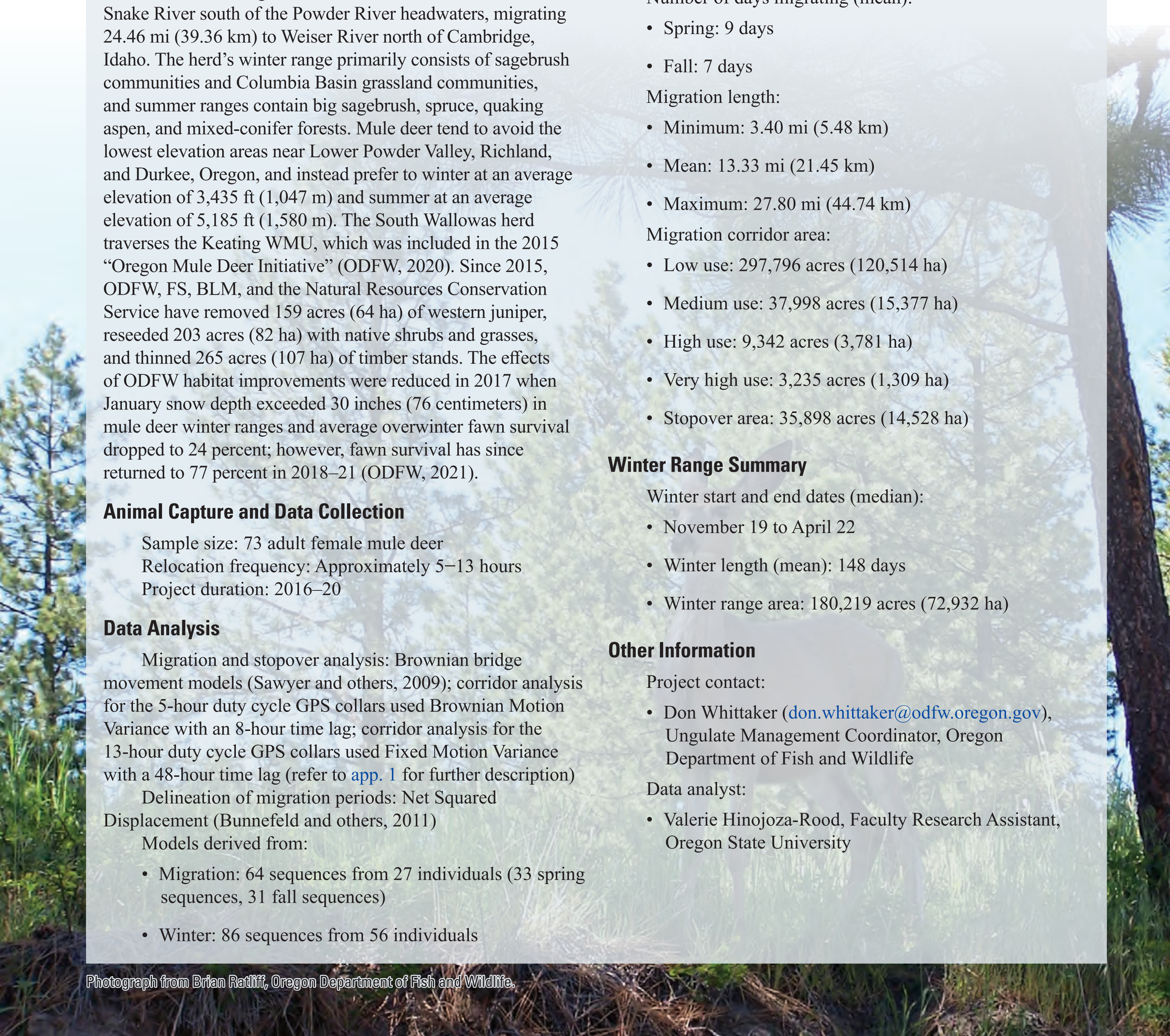
Other Information

Project contact:

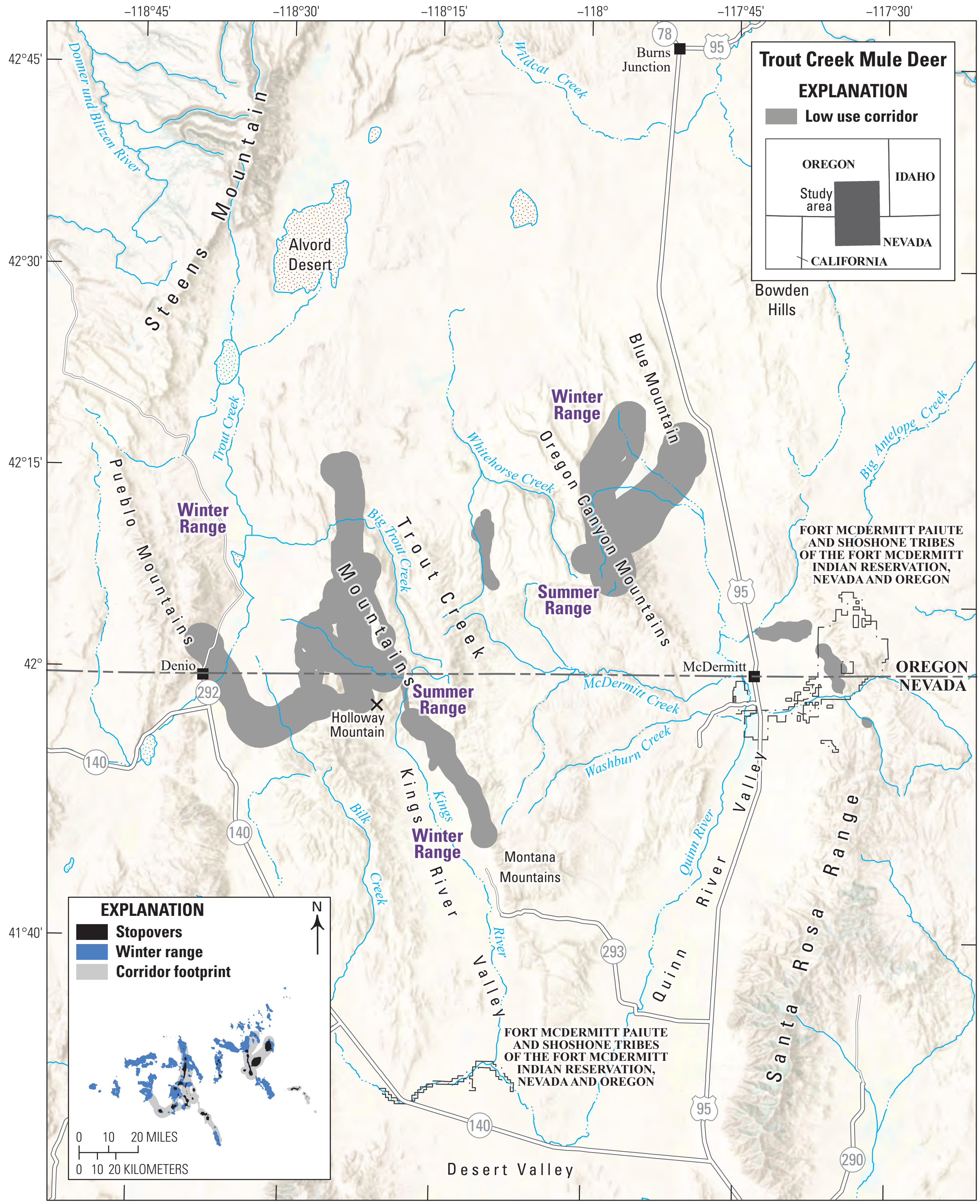
- Don Whittaker (don.whittaker@odfw.oregon.gov), Ungulate Management Coordinator, Oregon Department of Fish and Wildlife

Data analyst:

- Valerie Hinojoza-Rood, Faculty Research Assistant, Oregon State University



Photograph from Brian Ratliff, Oregon Department of Fish and Wildlife.



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U.S. Geological Survey digital data, 2019
Universal Transverse Mercator, zone 11 north
North American Datum of 1983

0 4 8 12 16 20 MILES
0 4 8 12 16 20 KILOMETERS

Figure 18. Migration corridors, stopovers, summer ranges, and winter ranges of the Trout Creek mule deer herd.

Oregon | Mule Deer

Trout Creek Mule Deer

The Trout Creek mule deer herd comprises residents and migrants making short-range elevational migrations. Trout Creek mule deer mainly winter at lower elevations surrounding Blue Mountain and the slopes of the Oregon Canyon Mountains (fig. 18). In spring, some of these mule deer migrate to higher elevations in the Oregon Canyon Mountains. Other individuals winter in the southwestern part of the herd's range, inhabiting areas near Kings River Valley, the Pueblo Mountains, and the foothills of the Trout Creek Mountains. These mule deer migrate to summer ranges on the crests of Holloway Mountain and the Trout Creek Mountains. Notably, one GPS-collared mule deer formerly wintering on the Trout Creek Mountains migrated south from a summer range on the Oregon-Nevada border to the Montana Mountains during the second documented winter before returning to Oregon in spring. Habitat on winter ranges consists of *A. t. wyomingensis* (Wyoming big sagebrush) plant communities and nonnative annual grasslands. Summer ranges consist mainly of native grasslands, mountain big sagebrush plant communities, and mountain shrub communities.

The Trout Creek mule deer herd faces several threats including summer wildfires, highway barriers, and resource competition. In 2012, the Holloway fire burned 462,017 acres (186,972 ha) including most of the Trout Creek and Oregon Canyon Mountains and resulted in the temporary loss of shrub cover at higher elevations and conversion of native forbs and shrubland to invasive annual grasses at lower elevations. Although no migratory mule deer attempt to cross U.S. Highway 95, some resident mule deer have ranges spanning the busy highway, which had an AADT value of 2,095 vehicles in 2018. The Trout Creek mule deer herd also borders the Barren Creek Complex HMA to the north and the Beaty Butte HMA to the east (BLM, 2020, 2022). The Barren Creek Complex HMA contains approximately 2,500 feral horses and the Beaty Butte HMA contains 463 feral horses. Both feral horse populations surpass the maximum appropriate management levels of 892 and 250 horses, respectively, suggesting mule deer and horses compete for resources in the few areas where ranges overlap.

Animal Capture and Data Collection

Sample size: 34 adult female mule deer

Relocation frequency: Approximately 5 hours

Project duration: 2020–present (data through July 2022 analyzed for this report)

Data Analysis

Migration and stopover analysis: Brownian bridge movement models (Sawyer and others, 2009; refer to app. 1 for further description)

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

Models derived from:

- Migration: 40 sequences from 10 individuals (24 spring sequences, 16 fall sequences)
- Winter: 51 sequences from 28 individuals

Migration use classifications:

- Low: Used by at least one individual

Migration and Stopover Summary

Migration start and end dates (median):

- Spring: April 17 to April 19
- Fall: December 3 to December 8

Number of days migrating (mean):

- Spring: 11 days
- Fall: 3 days

Migration corridor length:

- Minimum: 4.43 mi (7.12 km)
- Mean: 9.92 mi (15.96 km)
- Maximum: 16.76 mi (26.97 km)

Migration corridor area:

- Low use: 198,880 acres (80,484 ha)
- Stopover area: 27,478 acres (11,120 ha)

Winter Range Summary

Winter start and end dates (median):

- December 9 to April 14
- Winter length (mean): 139 days
- Winter range area: 178,057 acres (72,057 ha)

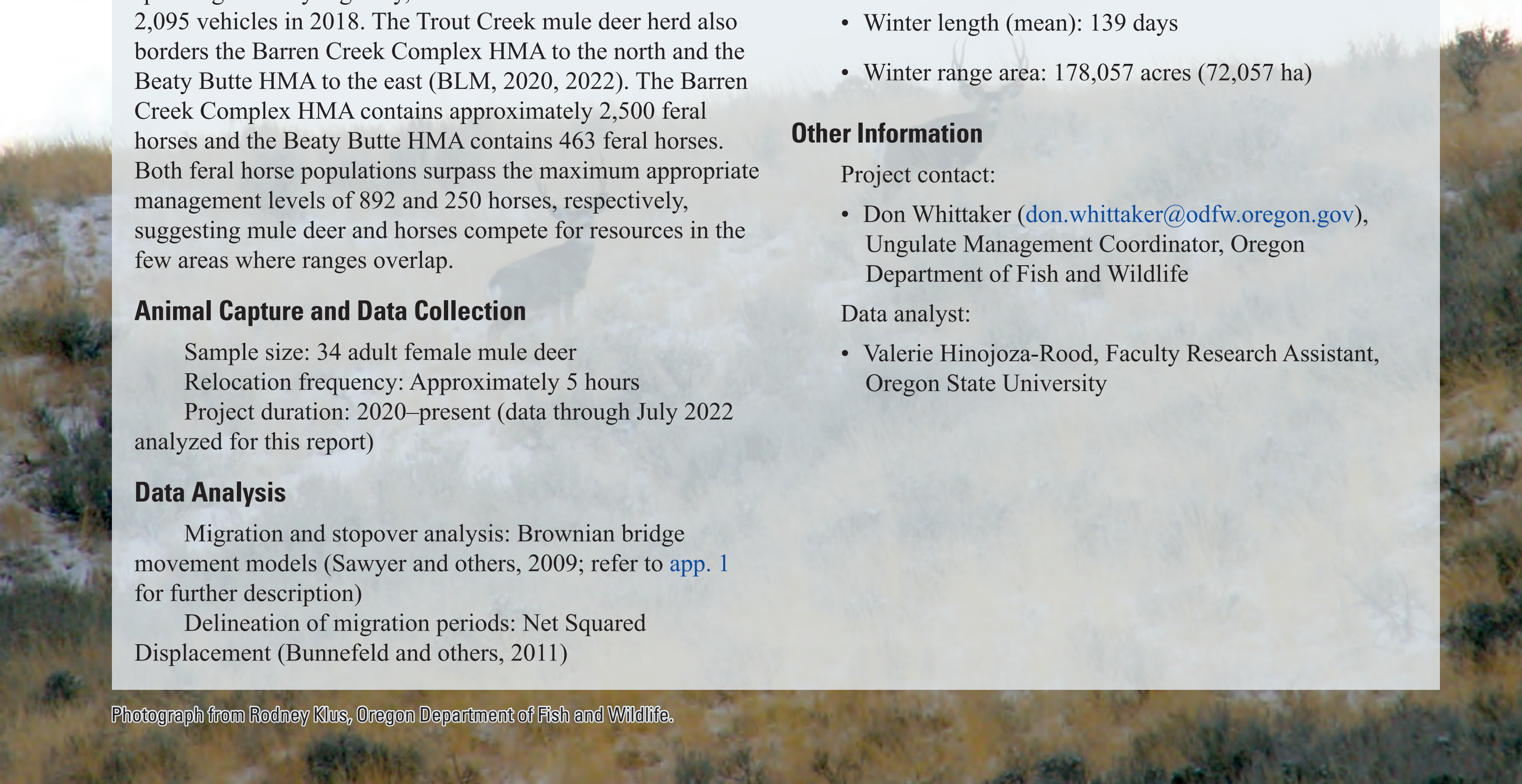
Other Information

Project contact:

- Don Whittaker (don.whittaker@odfw.oregon.gov), Ungulate Management Coordinator, Oregon Department of Fish and Wildlife

Data analyst:

- Valerie Hinojoza-Rood, Faculty Research Assistant, Oregon State University



Photograph from Rodney Klus, Oregon Department of Fish and Wildlife.

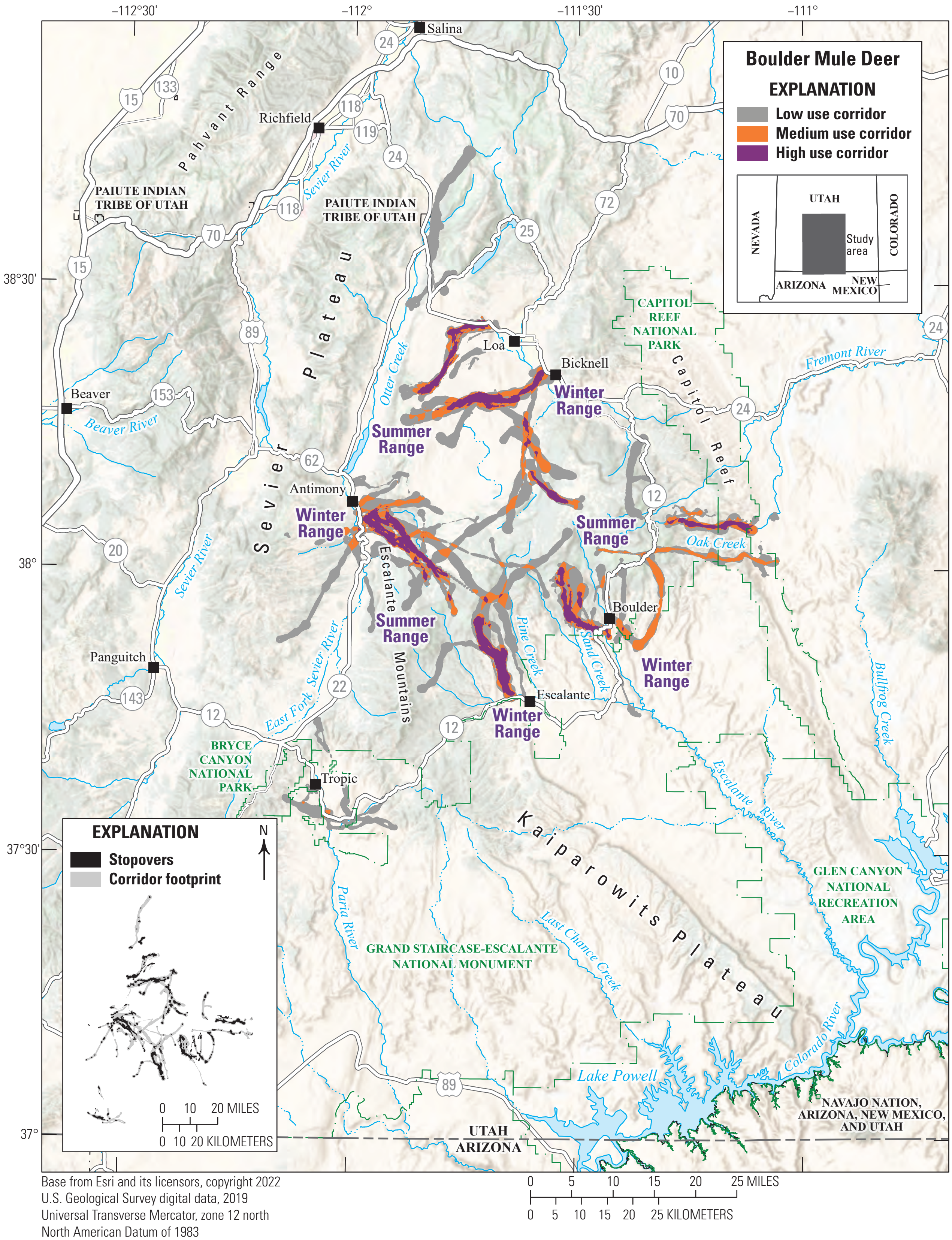


Figure 19. Migration corridors, stopovers, summer ranges, and winter ranges of the Boulder mule deer herd.

Utah | Mule Deer

Boulder Mule Deer

The Boulder mule deer WMU is part of the high plateau complex in southern Utah. The unit encompasses 1.3 million acres (526,091 ha) including BLM, FS, and State lands and small amounts of private lands on the periphery. Approximately 7,000 mule deer inhabit the area. In 2019, 112 GPS collars were deployed on Boulder mule deer to describe migratory corridors and determine the significance of the winter ranges to the herd. GPS-collar data indicated the Boulder mule deer herd is migratory; mule deer use high-elevation habitats on FS lands in the summer and low-elevation habitats on BLM and State lands in the winter (fig. 19). Herd movements appear complex because mule deer sharing the same summer range have the option to migrate to many different winter ranges. A better understanding of the herd's movements is critical for managing the herd and keeping corridors and winter ranges intact.

Animal Capture and Data Collection

Sample size: 82 adult mule deer (20 males, 61 females, 1 unknown)

Relocation frequency: Approximately 2–3 hours

Project duration: 2019–present

Data Analysis

Corridor and stopover analysis:Brownian bridge movement models (Sawyer and others, 2009) and Fixed Motion Variance (refer to app. 1 for further description)

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

Models derived from:

- Migration: 219 sequences from 82 individuals (125 spring sequences, 94 fall sequences)

Migration use classifications:

- Low: Used by 0–25 percent of the individuals
- Medium: Used by 25–75 percent of the individuals
- High: Used by >75 percent of the individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: May 14 to May 15
- Fall: October 12 to October 13

Number of days migrating (mean):

- Spring: 6 days
- Fall: 14 days

Migration length:

- Minimum: 1.74 mi (2.80 km)
- Mean: 11.57 mi (18.62 km)
- Maximum: 30.81 mi (49.58 km)

Migration corridor area:

- Low use: 313,163 acres (126,723 ha)
- Medium use: 103,562 acres (41,910 ha)
- High use: 46,214 acres (18,702 ha)
- Stopover area: 88,835 acres (35,950 ha)

Other Information

Utah mule deer migration data are kept up to date and are viewable at the Utah Division of Wildlife Resources Wildlife Migration Initiative webpage (Utah Division of Wildlife Resources, 2023). Data used in this study may be made available upon approval by Utah Division of Wildlife Resources.

Project contact:

- Blair Stringham (blairstringham@utah.gov), Wildlife Migration Initiative Coordinator, Utah Division of Wildlife Resources

Data analyst:

- Jessie Shapiro, Wildlife Migration GIS Specialist, Utah Division of Wildlife Resources

Photograph from Utah Division of Wildlife Resources.

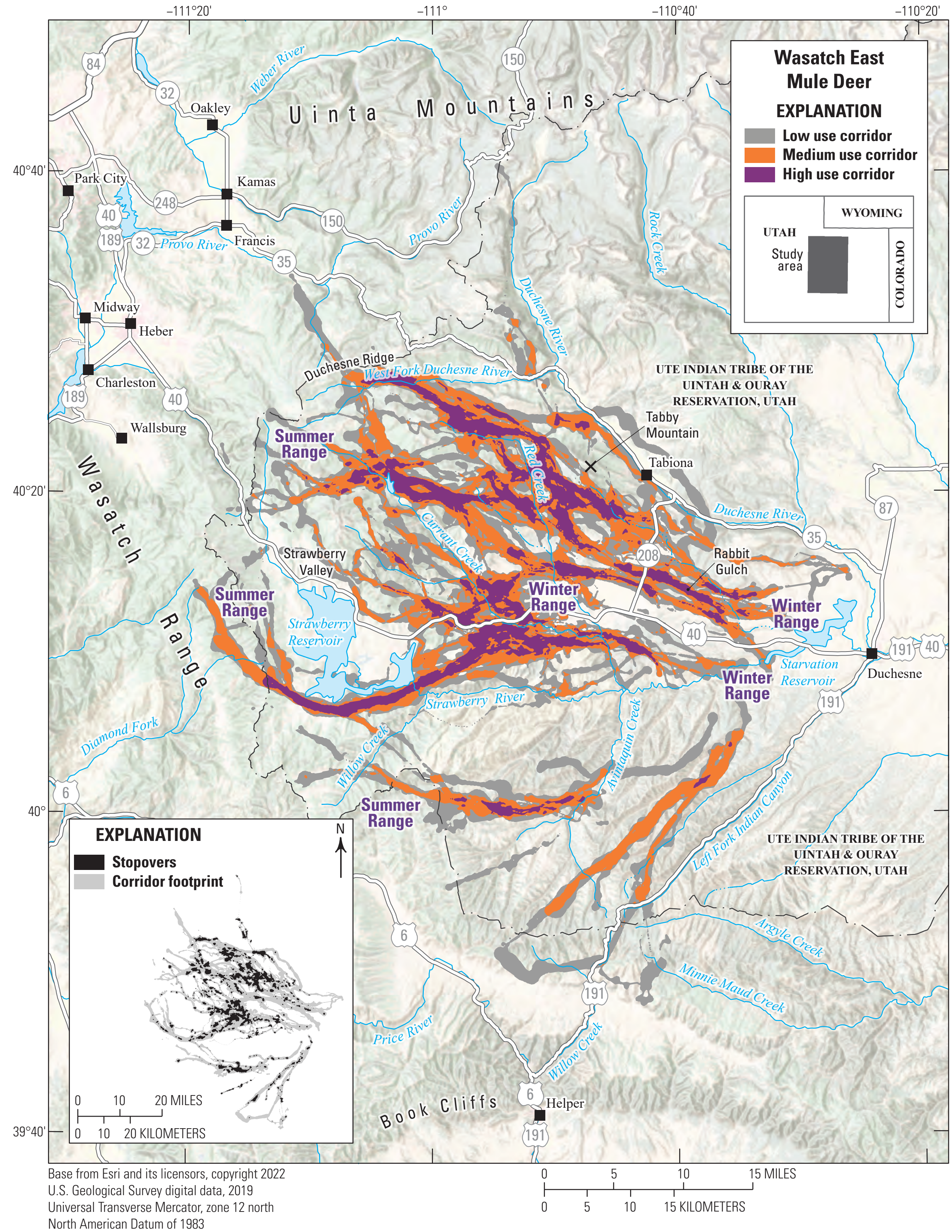


Figure 20. Migration corridors, stopovers, summer ranges, and winter ranges of the Wasatch East mule deer herd.

Utah | Mule Deer

Wasatch East Mule Deer

The Wasatch East mule deer herd resides on the eastern side of the Wasatch Range in central Utah. Annually, the Wasatch East mule deer migrate an average of 23 mi (37 km) between summer ranges along Duchesne Ridge, north of Strawberry Valley, and winter ranges west of Duchesne, Utah, near Tabby Mountain and Rabbit Gulch (fig. 20). Winter range habitat consists of pinyon-juniper woodlands, sagebrush-grass, and mountain browse communities. These habitat types are used heavily by wintering big game species and browsing availability is greatly reduced in severe winters, which pushes the Wasatch East mule deer herd into agricultural areas. The herd's winter range habitats are at high risk of habitat loss and degradation, threatened by conifer encroachment, expansion of invasive species, and increasing development. The Utah Division of Wildlife Resources is actively restoring sagebrush and other browse species to recover and enhance winter habitat for mule deer and other wildlife. Additionally, highway mortality is a significant concern for this herd because mule deer must traverse two major highways, U.S. Highway 40 and U.S. Highway 191. Bisecting this corridor, U.S. Highway 40, a major transportation corridor, has seen an upward trend of AADT and saw nearly 6,000 vehicles per day in 2020 (Utah Department of Transportation, 2023). Approximately 2,000 vehicles per day travel U.S. Highway 191 (Utah Department of Transportation, 2023), which forms the southeastern boundary of the Wasatch East mule deer herd. Cooperative efforts with the Utah Department of Transportation are underway to accurately implement mitigation measures on sections of both highways to reduce WVC.

Animal Capture and Data Collection

Sample size: 89 adult mule deer (41 males, 48 females)
Relocation frequency: 2–3 hours
Project duration: 2020–present

Data Analysis

Corridor and stopover analysis:Brownian bridge movement models (Sawyer and others, 2009) and Fixed Motion Variance (refer to app. 1 for further description)

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

Models derived from:

- Migration: 238 sequences from 89 individuals (151 spring sequences, 87 fall sequences)

Migration use classifications:

- Low: Used by 0–25 percent of the individuals
- Medium: Used by 25–75 percent of the individuals
- High: Used by >75 percent of the individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: May 1 to May 15
- Fall: October 20 to February 11

Number of days migrating (mean):

- Spring: 25 days
- Fall: 33 days

Migration corridor length:

- Minimum: 1.32 mi (2.12 km)
- Mean: 23.05 mi (37.10 km)
- Maximum: 45.24 mi (72.81 km)

Migration corridor area:

- Low use: 361,809 acres (146,418 ha)
- Medium use: 184,234 acres (74,556 ha)
- High use: 61,774 acres (24,999 ha)
- Stopover area: 76,896 acres (31,118 ha)

Other Information

Utah mule deer migration data are kept up to date and are viewable at the Utah Division of Wildlife Resources Wildlife Migration Initiative webpage (Utah Division of Wildlife Resources, 2023). Data used in this study may be made available upon approval by Utah Division of Wildlife Resources.

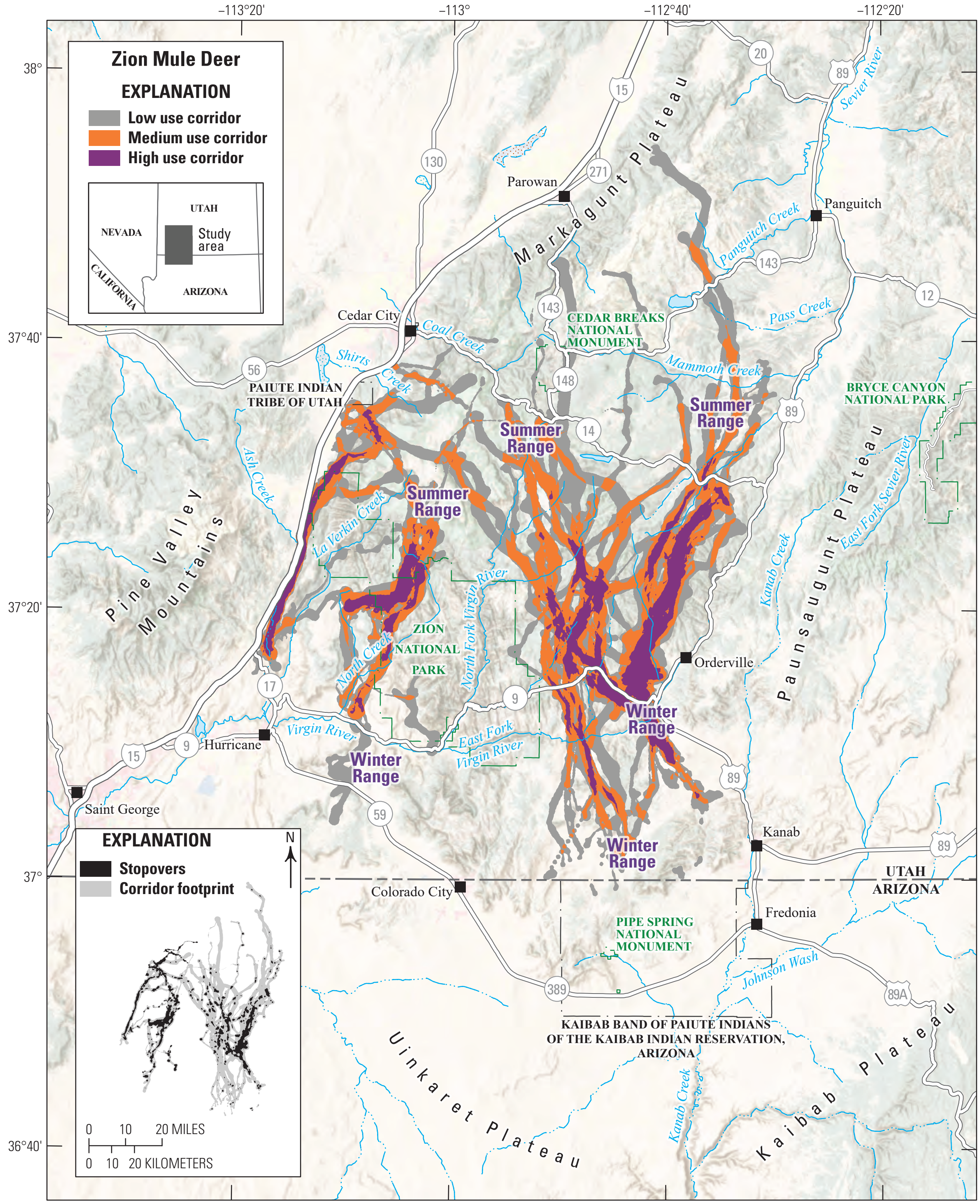
Project contact:

- Blair Stringham (blairstringham@utah.gov), Wildlife Migration Initiative Coordinator, Utah Division of Wildlife Resources

Data analyst:

- Jessie Shapiro, Wildlife Migration GIS Specialist, Utah Division of Wildlife Resources

Photograph from Utah Division of Wildlife Resources.



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U.S. Geological Survey digital data, 2019
Universal Transverse Mercator, zone 12 north
North American Datum of 1983

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

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

Utah | Mule Deer

Zion Mule Deer

The Zion mule deer herd inhabits the Zion WMU in southern Utah, is one of the larger deer herds in the State, and has approximately 18,000 animals. The Zion WMU has a unique assemblage of flora and fauna in addition to various geographical configurations such as canyons, buttes, mesas, and natural arches. Land ownership is a complex mix of BLM, NPS, FS, and private lands. A significant portion of the Zion mule deer herd's summer and winter habitats is on private land. The BLM, FS, and Zion National Park administrate the remaining portions (fig. 21). Data from GPS-collared mule deer indicated most mule deer are migratory, traveling north and south to reach their respective seasonal ranges. Additionally, mule deer must navigate State Route 9, which connects nearby major cities to Zion National Park. As a result, urban development and WVC are the herd's predominant challenges in this migration corridor. The Utah Division of Wildlife Resources continues to work closely with landowners and land management agencies to protect and enhance existing, crucial mule deer habitat and mitigate losses because of natural and human effects.

Animal Capture and Data Collection

Sample size: 78 adult mule deer (29 males, 49 females)
Relocation frequency: Approximately 2−3 hours
Project duration: 2019–present

Data Analysis

Corridor and stopover analysis: Brownian bridge movement models (Sawyer and others, 2009) and Fixed Motion Variance (refer to app. 1 for further description)

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

Models derived from:

- Migration: 295 sequences from 78 individuals (174 spring sequences, 121 fall sequences)

Migration use classifications:

- Low: Used by 0–25 percent of the individuals
- Medium: Used by 25–75 percent of the individuals
- High: Used by >75 percent of the individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: April 25 to May 9
- Fall: October 8 to October 24

Number of days migrating (mean):

- Spring: 18 days
- Fall: 16 days

Migration corridor length:

- Minimum: 3.13 mi (5.04 km)
- Mean: 21.36 mi (34.38 km)
- Maximum: 50.18 mi (80.76 km)

Migration corridor area:

- Low use: 407,015 acres (164,712 ha)
- Medium use: 198,542 acres (80,347 ha)
- High use: 67,302 acres (27,236 ha)
- Stopover area: 87,994 acres (35,609 ha)

Other Information

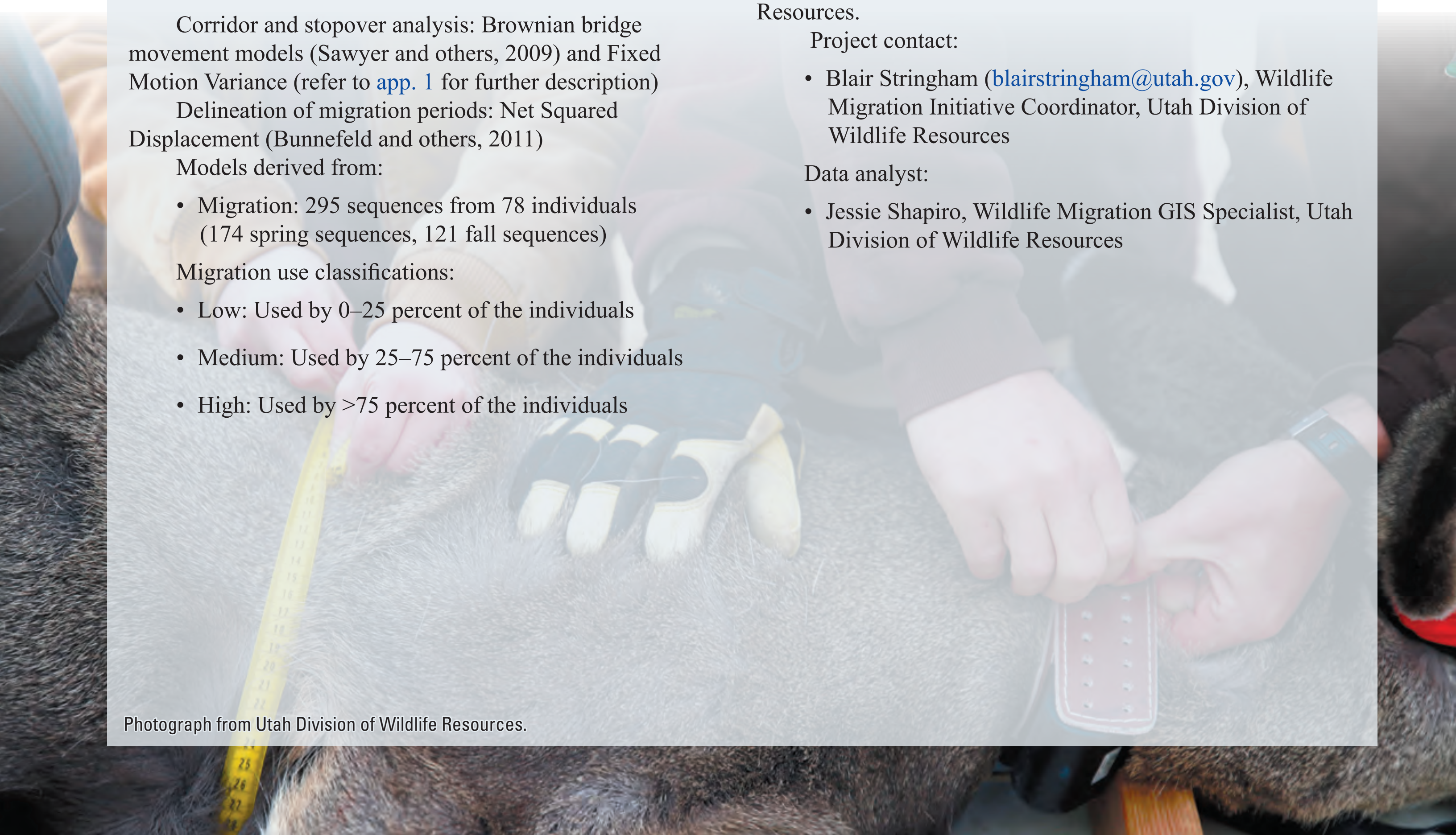
Utah mule deer migration data are kept up to date and are viewable at the Utah Division of Wildlife Resources Wildlife Migration Initiative webpage (Utah Division of Wildlife Resources, 2023). Data used in this study may be made available upon approval by Utah Division of Wildlife Resources.

Project contact:

- Blair Stringham (blairstringham@utah.gov), Wildlife Migration Initiative Coordinator, Utah Division of Wildlife Resources

Data analyst:

- Jessie Shapiro, Wildlife Migration GIS Specialist, Utah Division of Wildlife Resources



Photograph from Utah Division of Wildlife Resources.

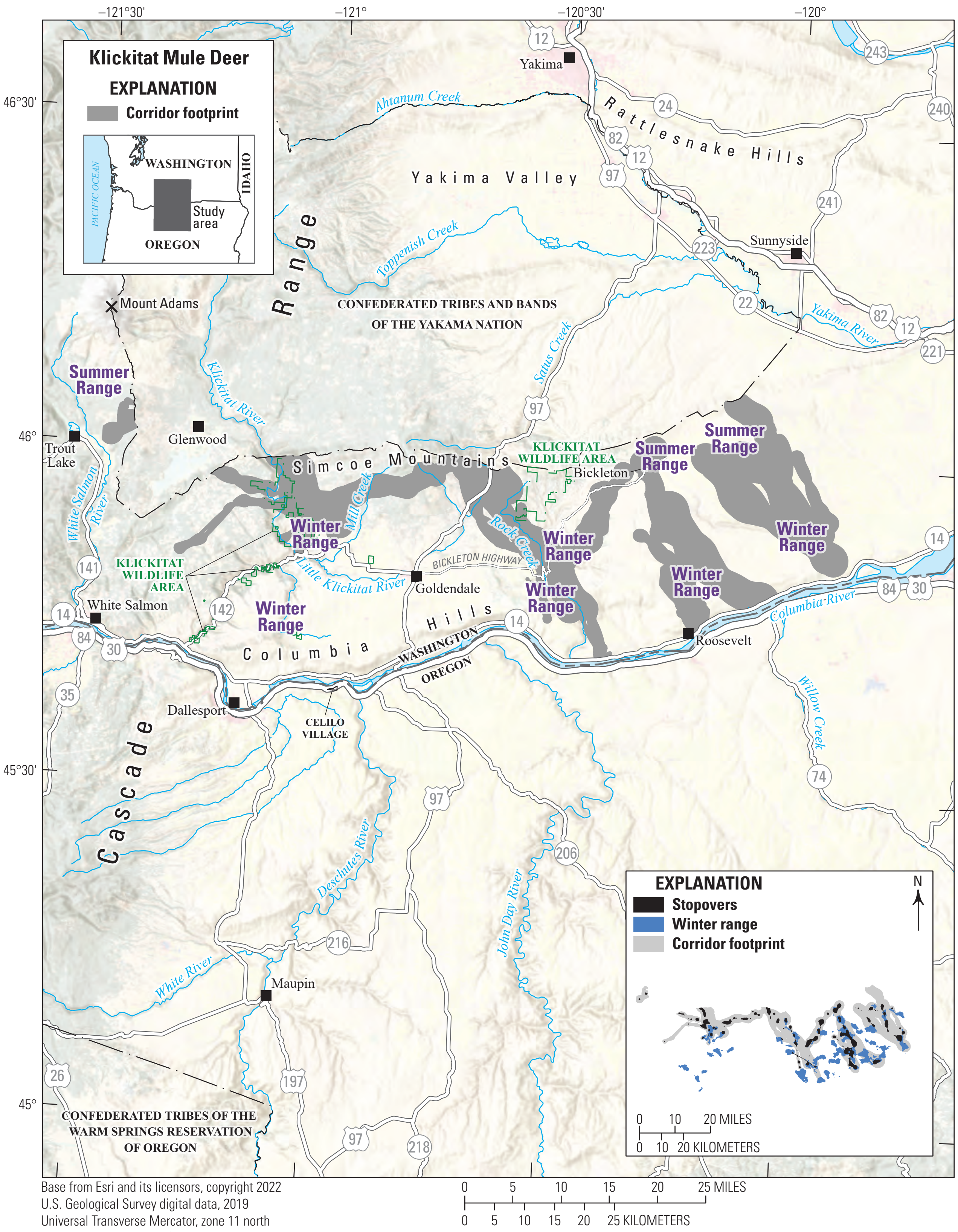


Figure 22. Migration corridors, stopovers, summer ranges, and winter ranges of the Klickitat mule deer herd. Parts of the corridor footprint overlapping Confederated Tribes and Bands of the Yakama Nation lands are not shown.

Washington | Mule Deer

Klickitat Mule Deer

The Klickitat mule deer herd inhabits the Columbia Hills and surrounding terrain to the north along the Columbia River, Washington (fig. 22). Klickitat River bounds the western edge of the herd's range and is part of a transition zone between black-tailed deer and mule deer distributions. Habitats in the western half of the herd's range include *Quercus garryana* (Oregon white oak) mixed with *Abies* spp. (fir), pine, or grassland species. The western half of the herd's range comprises a mix of public and private lands, including rangeland, farmland, and the Klickitat Wildlife Area, which has protected crucial winter range since the 1950s. Sagebrush steppe is more prevalent in the eastern half of the herd's range with Oregon white oak and ponderosa pine in drainages, such as Rock Creek, which serves as a popular wintering area. Dryland wheat, rangeland, and viticulture are also common in the eastern half of the herd's range, which is mostly privately owned.

Klickitat mule deer are partially migratory; more residents inhabit the eastern half of the herd's range, and a higher proportion of migrants are in the western half of the herd's range. As vegetation green up progresses during spring, migrants travel from low-elevation winter ranges to high-elevation summer ranges in the Cascade Range and Simcoe Mountains. Some individuals migrate short distances (5 mi [8 km]), especially mule deer in the eastern half of the herd's range. Increasing residential development in the western half of the range, and renewable energy development and conversion to viticulture in the eastern half of the range, are the greatest concerns for winter ranges and migration corridors. Additionally, U.S. Highway 97 is a semipermeable barrier to migration and only has one wildlife underpass, which was built in 2012.

Animal Capture and Data Collection

Sample size: 103 adult female mule deer

Relocation frequency: Approximately 4 hours

Project duration: 2021–present (data through December 2022 analyzed for this report)

Data Analysis

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

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

Models derived from:

- Migration: 78 sequences from 32 individuals (39 spring sequences, 39 fall sequences)
- Winter: 76 sequences from 76 individuals

Migration use classifications:

- Corridor footprint: Used by at least one individual

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: April 12 to April 20
- Fall: November 2 to November 6

Number of days migrating (mean):

- Spring: 8 days
- Fall: 11 days

Migration length:

- Minimum: 5.24 mi (8.44 km)
- Mean: 14.61 mi (23.51 km)
- Maximum: 30.20 mi (48.61 km)

Migration corridor area:

- Corridor footprint: 424,898 acres (171,950 ha)
- Stopover area: 51,560 acres (20,866 ha)

Winter Range Summary

Winter start and end dates (median):

- November 6 to April 10
- Winter length (mean): 149 days
- Winter range area: 96,502 acres (39,053 ha)

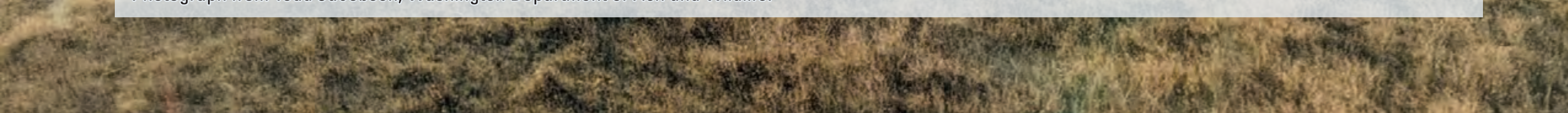
Other Information

Project contacts:

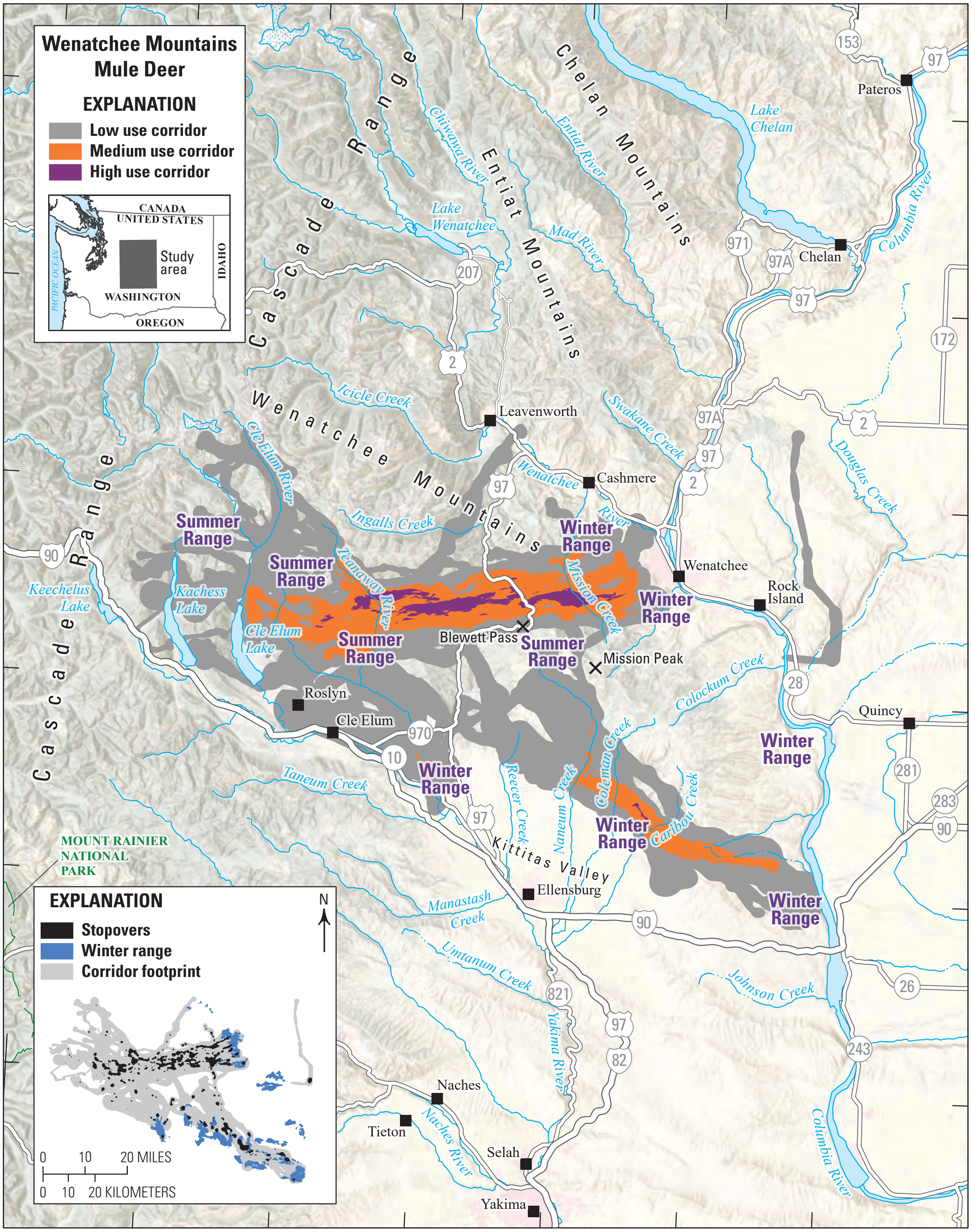
- Stefanie Bergh (stefanie.bergh@dfw.wa.gov), District Wildlife Biologist, Washington Department of Fish and Wildlife
- Samantha Bundick (samantha.bundick@dfw.wa.gov), Ungulate Specialist, Washington Department of Fish and Wildlife

Data analysts:

- Brendan Oates, Ungulate Specialist, Washington Department of Fish and Wildlife
- Samantha Bundick, Ungulate Specialist, Washington Department of Fish and Wildlife



Photograph from Todd Jacobsen, Washington Department of Fish and Wildlife.



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

Figure 23. Migration corridors, stopovers, summer ranges, and winter ranges of the Wenatchee Mountains mule deer herd.

Washington | Mule Deer

Wenatchee Mountains Mule Deer

The Wenatchee Mountains mule deer herd inhabits a matrix of private and public lands along the eastern slope of the Cascade Range in Washington (fig. 23). Historically, the Wenatchee Mountains mule deer herd was separated into two subherds, Chelan and Kittitas; however, recent GPS-collar data indicated the mule deer south of U.S. Highway 2 and north of Interstate 90 represent one herd. Their high use winter range extends along the foothills west and south of Wenatchee, Washington, and throughout the foothills of Kittitas Valley near Ellensburg, Washington. Their low use winter range occurs along the foothills west of the Columbia River north of Interstate 90. In the spring, migratory mule deer travel west into the Wenatchee Mountains to their summer range, which includes regional wilderness areas.

Between 2020 and 2021, collaring efforts focused on the foothills near Wenatchee, Washington, and in the surrounding foothills near Ellensburg. Collar data analysis indicated the Wenatchee Mountains mule deer herd is partially migratory. A high proportion of migratory mule deer inhabit the northern winter range of the Wenatchee Mountains, and residents more commonly inhabit the foothills of Kittitas Valley. In 2022, collaring efforts in the northern winter range foothills near Wenatchee targeted the higher proportion of the migratory herd of mule deer, to more clearly identify the movement corridors intersecting U.S. Highway 97 near Blewett Pass. The herd has several challenges, including the increasing frequency of large-scale wildfires and residential developments, which continue to degrade and reduce available winter habitat. Disturbance from human recreation on the winter range continues to be a concern. Additionally, U.S. Highway 97 and State Route 970 receive high volumes of traffic in the region and present semipermeable barriers to spring and fall migrations.

Animal Capture and Data Collection

Sample size: 121 adult female mule deer

Relocation frequency: Approximately 4 hours

Project duration: 2020–present (data through December 2022 analyzed for this report)

Data Analysis

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

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

Models derived from:

- Migration: 184 sequences from 59 individuals (99 spring sequences, 85 fall sequences)
- Winter: 151 sequences from 97 individuals

Migration use classifications:

- Low: Used by at least one individual
- Medium: Used by 10–20 percent of the individuals
- High: Used by >20 percent of the individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: April 29 to May 5
- Fall: October 27 to November 17

Number of days migrating (mean):

- Spring: 17 days
- Fall: 24 days

Migration corridor length:

- Minimum: 5.65 mi (9.09 km)
- Mean: 43.67 mi (27.14 km)
- Maximum: 82.38 mi (51.19 km)

Migration corridor area:

- Low use: 540,590 acres (218,769 ha)
- Medium use: 108,615 acres (43,955 ha)
- High use: 14,880 acres (6,022 ha)
- Stopover area: 58,126 acres (23,523 ha)

Winter Range Summary

Winter start and end dates (median):

- November 18 to April 30
- Winter length (mean): 153 days
- Winter range area: 79,319 acres (32,099 ha)

Other Information

Project contacts:

- Brendan Oates (brendan.oates@dfw.wa.gov), Ungulate Specialist, Washington Department of Fish and Wildlife
- Samantha Bundick (samantha.bundick@dfw.wa.gov), Ungulate Specialist, Washington Department of Fish and Wildlife
- Erin Wampole (erin.wampole@dfw.wa.gov), Assistant District Wildlife Biologist, Washington Department of Fish and Wildlife
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Data analyst:

- Brendan Oates, Ungulate Specialist, Washington Department of Fish and Wildlife

Photograph from Pete Lopushinsky, Washington Department of Fish and Wildlife.

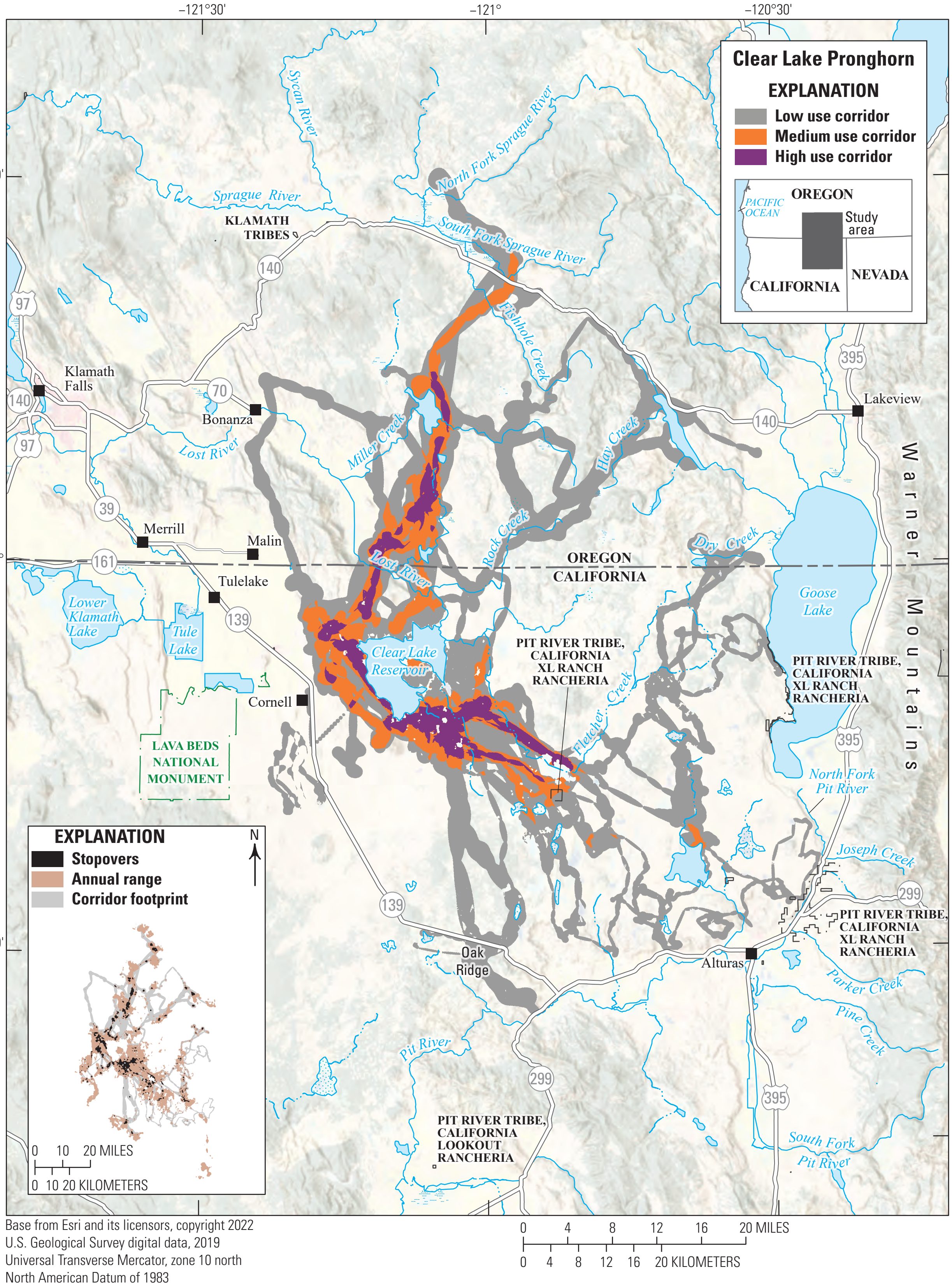


Figure 24. Migration corridors, stopovers, and annual ranges of the Clear Lake pronghorn herd.

California | Pronghorn

Clear Lake Pronghorn

The Clear Lake pronghorn herd contains migrants, but this herd does not migrate between traditional summer and winter seasonal ranges. Instead, much of the herd displays a nomadic tendency and slowly migrates north, east, or south for the summer using various high use areas as they move. Therefore, annual ranges were modeled using year-round data to demarcate high use areas instead of modeling specific winter ranges. A few GPS-collared pronghorn lived west of State Route 139 year round, seemingly separated from the rest of the herd by this highway barrier (fig. 24). However, some pronghorn crossed this road near Cornell, California, and joined this subgroup. Summer ranges were dispersed, and many individuals moved southeast through protected forests or crossed the State border into Oregon. A few outliers in the herd migrated long distances south, either crossing State Route 139 to Oak Ridge, or east into areas used by Likely Tables pronghorn (refer to the “Likely Tables Pronghorn” section in this report). Many of the collared pronghorn heavily used areas adjacent to Clear Lake Reservoir during winter. The Clear Lake pronghorn herd is declining (Trausch and others, 2020) because of drought, increasing fire frequency, invasive annual grasses, and juniper encroachment. Juniper removal on public and private lands could improve habitat quality and potentially reduce predation from mountain lions (Ewanyk, 2020).

Animal Capture and Data Collection

Sample size: 28 adult female pronghorn
Relocation frequency: Approximately 1–6 hours
Project duration: 2015–20

Data Analysis

Corridor, stopover, and annual range analysis: Brownian bridge movement models (Sawyer and others, 2009) and Fixed Motion Variance (refer to app. 1 for further description)

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

Models derived from:

- Migration: 72 sequences from 23 individuals
- Annual range: 47 sequences from 24 individuals

Migration use classifications:

- Low: Used by at least one individual
- Medium: Used by 10–20 percent of the individuals
- High: Used by >20 percent of the individuals

Corridor and Stopover Summary

Migration corridor length:

- Minimum: 4.16 mi (6.70 km)
- Mean: 31.18 mi (24.24 km)
- Maximum: 47.17 mi (75.92 km)

Migration corridor area:

- Low use: 515,481 acres (208,608 ha)
- Medium use: 114,516 acres (46,343 ha)
- High use: 40,214 acres (16,274 ha)
- Stopover area: 54,371 acres (22,003 ha)

Annual Range Summary

- Annual range (50 percent contour) area: 384,370 acres (155,549 ha)

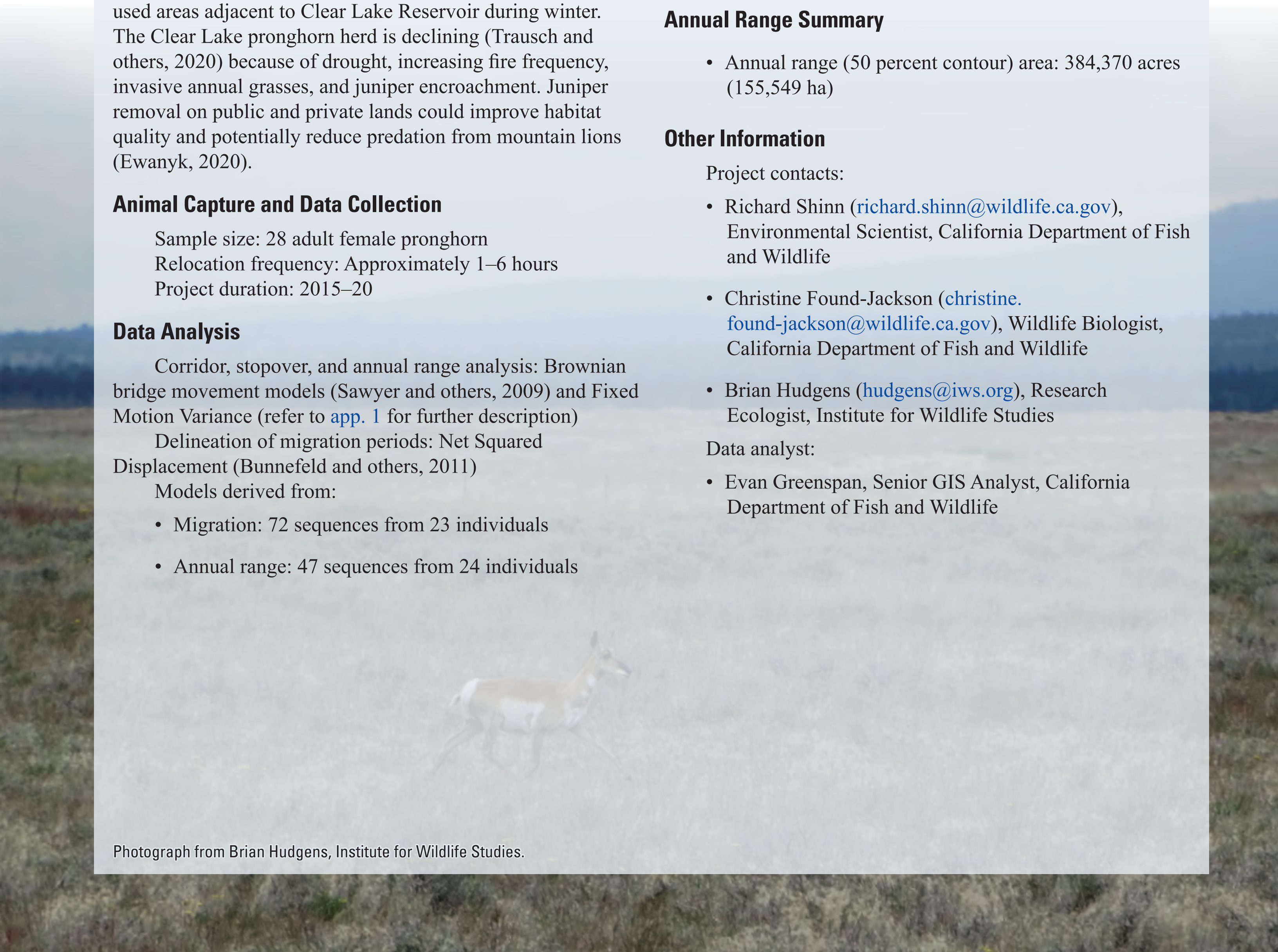
Other Information

Project contacts:

- Richard Shinn (richard.shinn@wildlife.ca.gov), Environmental Scientist, California Department of Fish and Wildlife
- Christine Found-Jackson (christine.found-jackson@wildlife.ca.gov), Wildlife Biologist, California Department of Fish and Wildlife
- Brian Hudgens (hudgens@iws.org), Research Ecologist, Institute for Wildlife Studies

Data analyst:

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



Photograph from Brian Hudgens, Institute for Wildlife Studies.

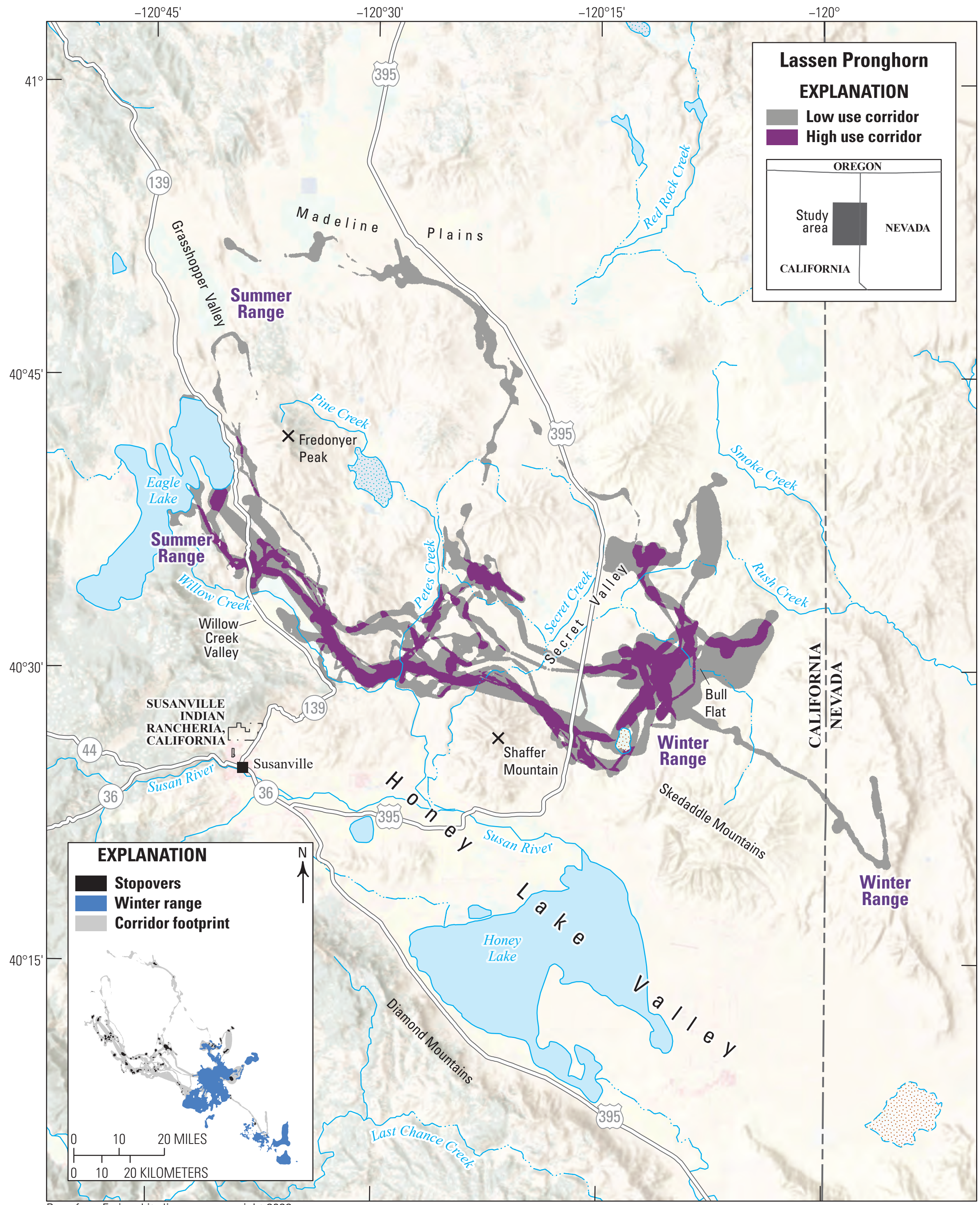


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Figure 25. Migration corridors, stopovers, and winter ranges of the Lassen pronghorn herd.

California | Pronghorn

Lassen Pronghorn

The Lassen pronghorn herd winters in lower elevations in Secret Valley, Bull Flat, and wilderness areas east of Shaffer Mountain and northeast of the Skedaddle Mountains. Summer ranges are dispersed with some pronghorn migrating north to the Madeline Plains and other pronghorn heading west to Willow Creek Valley, Grasshopper Valley, and Eagle Lake (fig. 25). An unknown portion of the herd is better characterized as residents. The primary threat to the Lassen herd is the conversion of perennial shrublands to nonnative, annual grasslands following wildfires. The 2012 Rush fire burned 271,911 acres (110,038 ha) in Lassen County by the herd's boundary and expanded nonnative annual grasslands with altered fire regimes, which increase fire frequency and promote further expansion of nonnative grasses. Overabundant feral horses and burros regularly exceed the appropriate management level, potentially reducing forage and water available for pronghorn (California Department of Fish and Wildlife, 2022). The expansion of juniper into shrub-steppe habitat reduces the forage available to pronghorn and increases the risk of mountain lion predation. Since the 1992–93 winter die off in northeastern California, the herd has been stable or slightly increasing with an average of 974 pronghorn counted during aerial winter surveys (B. Ehler, California Department of Fish and Wildlife, written commun., 2023). California Department of Fish and Wildlife plans to deploy 35 pronghorn GPS collars in winter 2024 to estimate the herd size using mark-resight surveys.

Animal Capture and Data Collection

Sample size: 7 adult female pronghorn
Relocation frequency: Approximately 1–6 hours
Project duration: 2015–17

Data Analysis

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

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

Models derived from:

- Migration: 14 sequences from 7 individuals (8 spring sequences, 6 fall sequences)
- Winter: 9 sequences from 6 individuals

Migration use classifications:

- Low: Used by at least one individual
- High: Used by >20 percent of the individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: March 10 to April 6
- Fall: October 19 to October 23

Number of days migrating (mean):

- Spring: 28 days
- Fall: 6 days

Migration corridor length:

- Minimum: 6.18 mi (9.95 km)
- Mean: 22.56 mi (36.30 km)
- Maximum: 36.39 mi (58.73 km)

Migration corridor area:

- Low use: 112,603 acres (45,569 ha)
- High use: 33,902 acres (13,720 ha)
- Stopover area: 11,490 acres (4,650 ha)

Winter Range Summary

Winter start and end dates (median):

- October 23 to March 14
- Winter length (mean): 148 days
- Winter range area: 72,722 acres (29,430 ha)

Other Information

Project contacts:

- Brian Ehler (brian.ehler@wildlife.ca.gov), Environmental Scientist, California Department of Fish and Wildlife
- Christine Found-Jackson (christine.found-jackson@wildlife.ca.gov), Wildlife Biologist, California Department of Fish and Wildlife
- Brian Hudgens (hudgens@iws.org), Research Ecologist, Institute for Wildlife Studies

Data analyst:

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

Photograph from Alexandra Avrin, California Department of Fish and Wildlife.

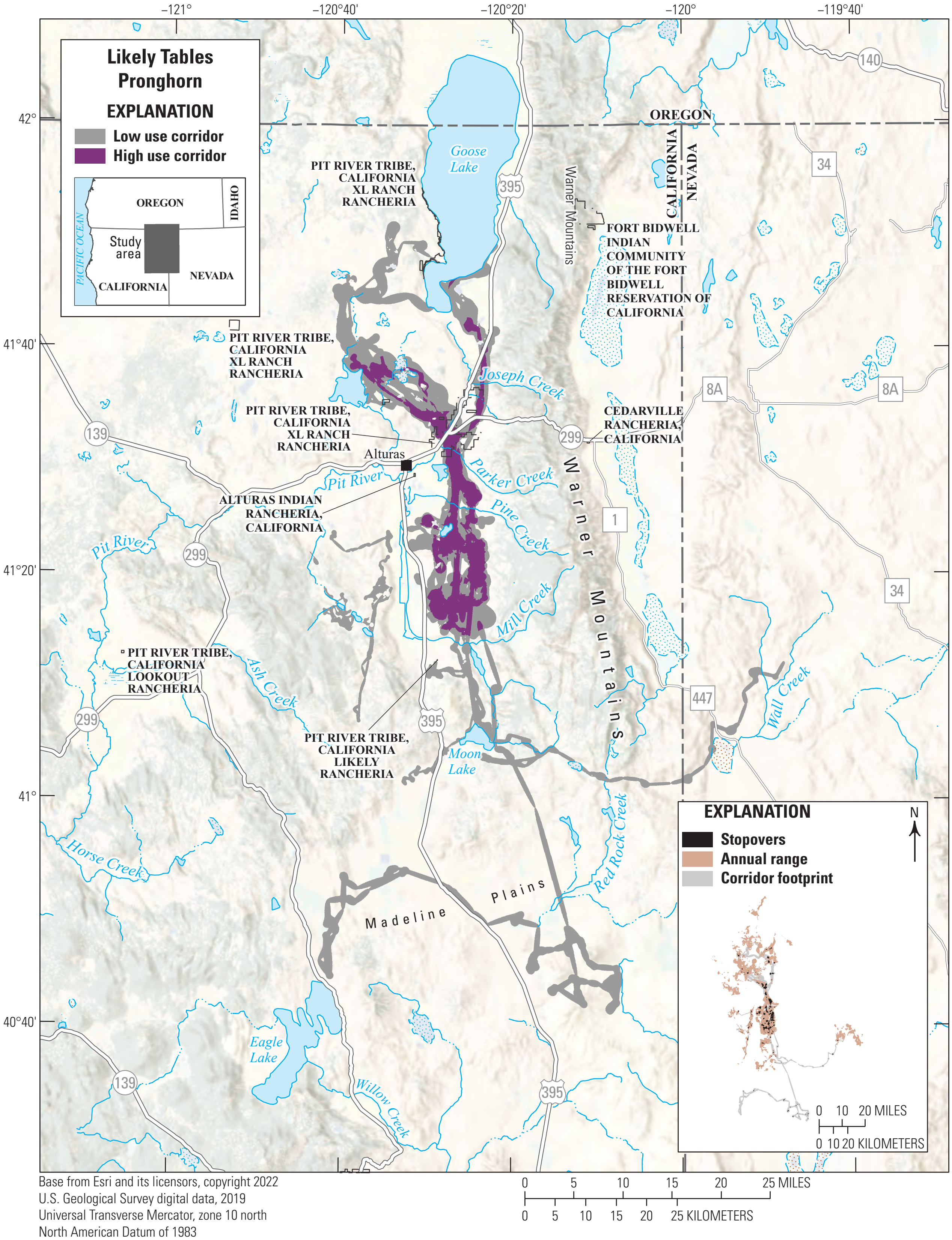


Figure 26. Migration corridors, stopovers, and annual ranges of the Likely Tables pronghorn herd.

California | Pronghorn

Likely Tables Pronghorn

The Likely Tables pronghorn herd contains migrants, but this herd does not migrate between traditional summer and winter seasonal ranges. Much of the herd displays a nomadic tendency and slowly migrates north for the summer using various high use areas as they move. Annual ranges were modeled using year-round data to demarcate high use areas instead of modeling specific winter ranges. However, during winter, many of the GPS-collared pronghorn heavily use an area west of the Warner Mountains, east of U.S. Highway 395, and north of Moon Lake (fig. 26). Some animals live year round in the agricultural fields and higher elevation prairies west of U.S. Highway 395. Little, if any, movement occurs by the herd across the highway, which is fenced on both sides of this area in the winter range. Summer ranges are dispersed with some pronghorn moving as far north as Goose Lake. A few outlier pronghorn in the herd move long distances south toward the Lassen pronghorn herd (refer to the “Lassen Pronghorn” section in this report) or east to Nevada. The Likely Tables pronghorn herd is declining because of drought, increasing fire frequency, invasive annual grasses, and juniper encroachment (Trausch and others, 2020). Juniper removal on public and private lands could improve habitat quality and potentially reduce predation from mountain lions (Ewanyk, 2020). Additionally, fences on public and private lands affect movement corridors and increase crossing or migration duration. However, recent fence modifications on BLM lands showed potential to reduce barriers to pronghorn movements (Hudgens, 2022).

Animal Capture and Data Collection

Sample size: 30 adult pronghorn (1 male, 29 females)
Relocation frequency: Approximately 1–4 hours
Project duration: 2014–20

Data Analysis

Corridor, stopover, and annual range analysis: Brownian bridge movement models (Sawyer and others, 2009) and Fixed Motion Variance (refer to app. 1 for further description)

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

Models derived from:

- Migration: 29 sequences from 17 individuals
- Annual range: 25 sequences from 20 individuals

Migration use classifications:

- Low: Used by at least one individual
- High: Used by >20 percent of the individuals

Corridor and Stopover Summary

Migration corridor length:

- Minimum: 4.85 mi (9.80 km)
- Mean: 23.62 mi (38.02 km)
- Maximum: 42.30 mi (68.07 km)

Migration corridor area:

- Low use: 224,967 acres (91,041 ha)
- High use: 50,249 acres (20,335 ha)
- Stopover area: 22,951 acres (9,288 ha)

Annual Range Summary

- Annual range (50 percent contour) area: 244,721 acres (99,035 ha)

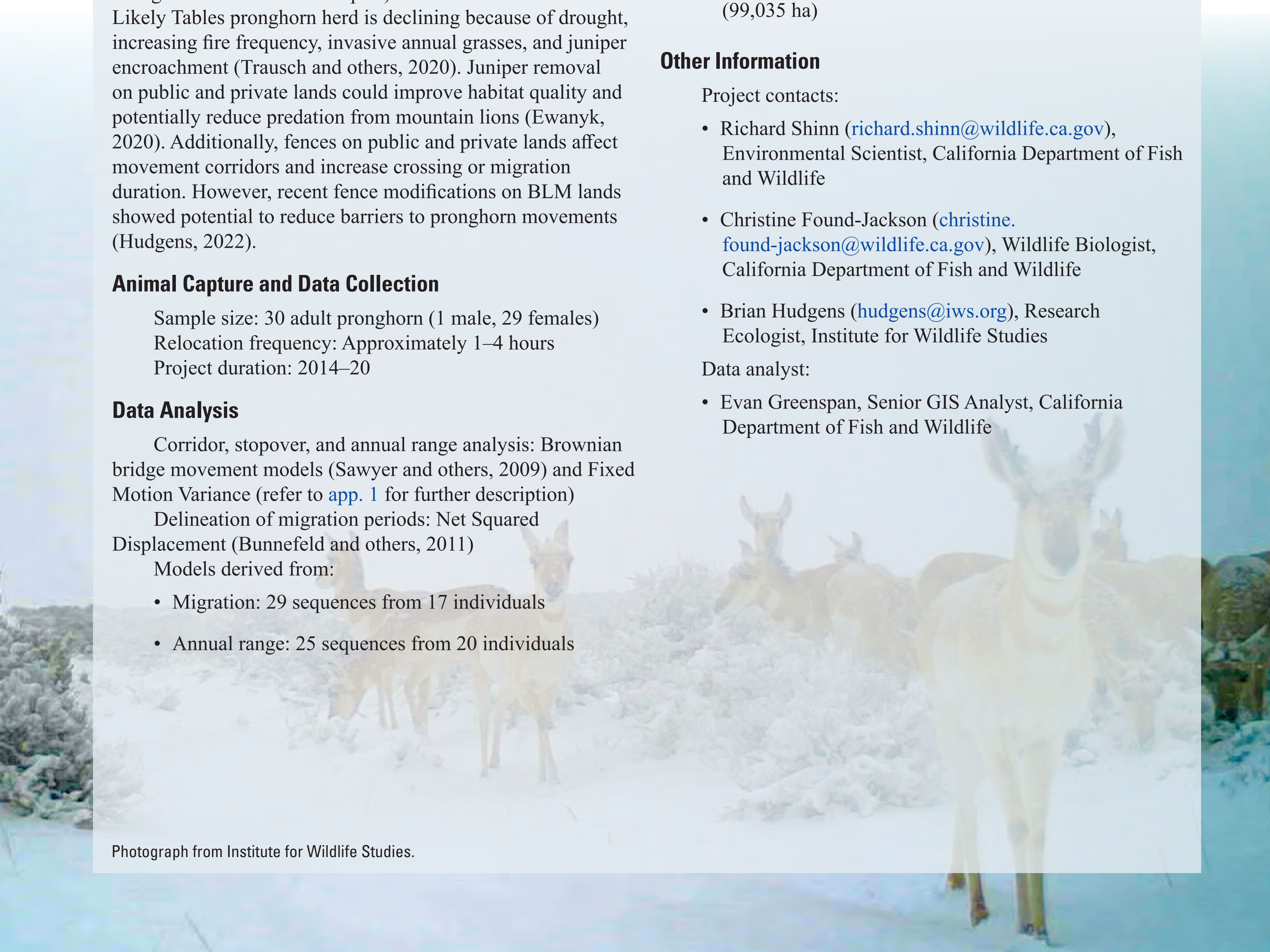
Other Information

Project contacts:

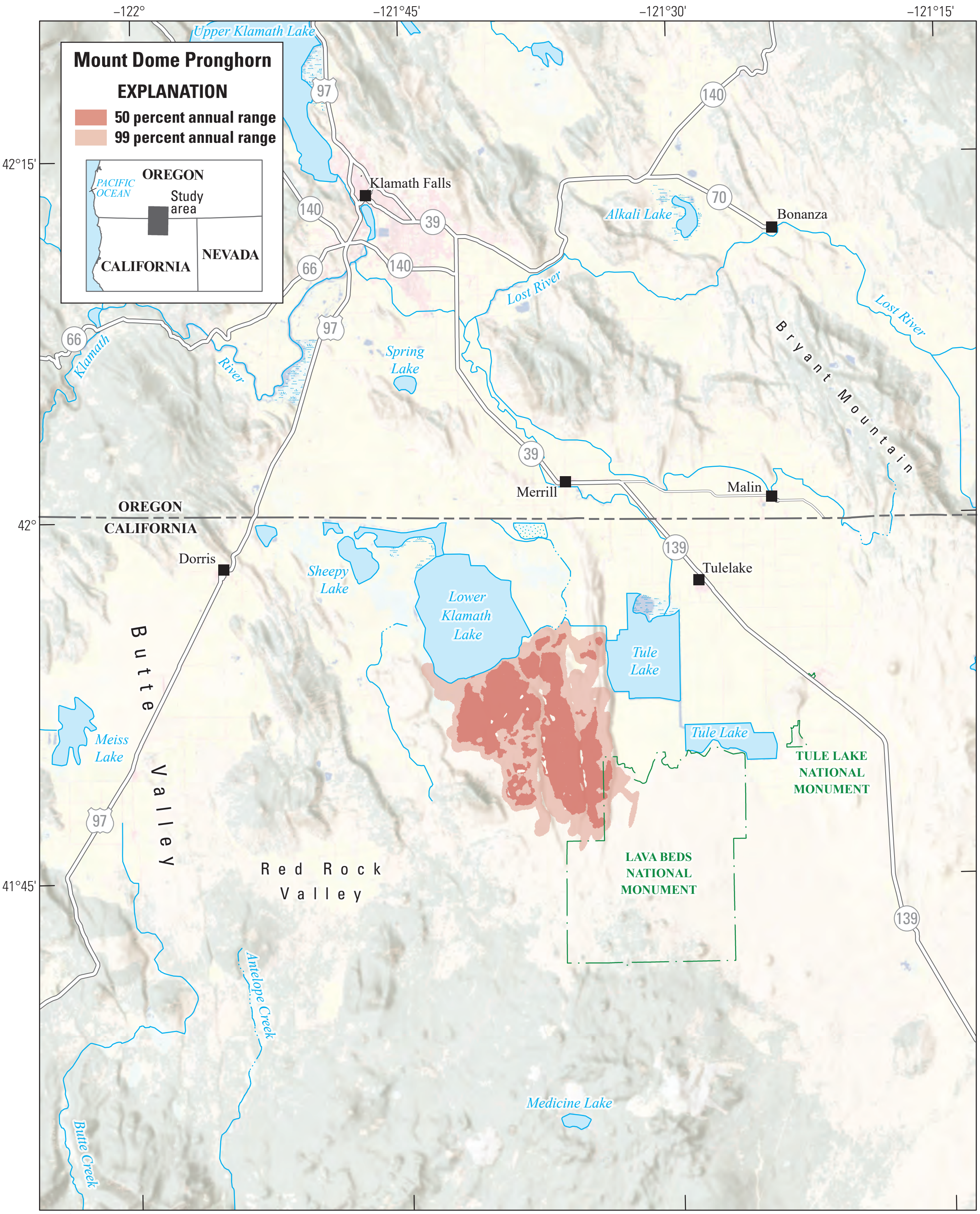
- Richard Shinn (richard.shinn@wildlife.ca.gov), Environmental Scientist, California Department of Fish and Wildlife
- Christine Found-Jackson (christine.found-jackson@wildlife.ca.gov), Wildlife Biologist, California Department of Fish and Wildlife
- Brian Hudgens (hudgens@iws.org), Research Ecologist, Institute for Wildlife Studies

Data analyst:

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



Photograph from Institute for Wildlife Studies.



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U.S. Geological Survey digital data, 2019
Universal Transverse Mercator, zone 10 north
North American Datum of 1983

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

Figure 27. Annual ranges of the Mount Dome pronghorn herd.

California | Pronghorn

Mount Dome Pronghorn

The Mount Dome pronghorn herd contains a mixture of residents and short-distance, elevation-based migrants, but this herd does not migrate between traditional summer and winter seasonal ranges. Instead, most of the herd displays a somewhat nomadic migratory tendency and slowly moves up or down elevational gradients. Long distance movements from this herd are rare because it is largely surrounded by geographic and human features restricting movement. Some pronghorn use higher elevation areas throughout the summer, although this pattern was not common. Therefore, annual home ranges were modeled using year-round data to demarcate high use areas (fig. 27). Mount Dome pronghorn numbers have declined significantly from historical highs but have remained relatively stable at low numbers in recent years (Trausch and others, 2020). Agricultural development in Butte Valley resulted in some loss of historical pronghorn habitat. Drought, increasing fire frequency, invasive annual grasses, and juniper encroachment negatively affect remaining, available habitat for pronghorn. Juniper removal on public and private lands has the potential to improve habitat quantity and quality (Ewanyk, 2020).

Animal Capture and Data Collection

Sample size: 9 adult female pronghorn
Relocation frequency: Approximately 1−2 hours
Project duration: 2019–20

Data Analysis

Annual range analysis: Brownian bridge movement models (Sawyer and others, 2009)
Models derived from:

- Annual range: 12 sequences from 9 individuals

Annual Range Summary

- Annual range (50 percent contour) area: 18,417 acres (7,453 ha)
- Annual range (99 percent contour) area: 36,604 acres (14,813 ha)

Other Information

Project contacts:

- Richard Shinn (richard.shinn@wildlife.ca.gov), Environmental Scientist, California Department of Fish and Wildlife
- Christine Found-Jackson (christine.found-jackson@wildlife.ca.gov), Wildlife Biologist, California Department of Fish and Wildlife
- Brian Hudgens (hudgens@iws.org), Research Ecologist, Institute for Wildlife Studies

Data analyst:

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

Photograph from Brian Hudgens, Institute for Wildlife Studies.

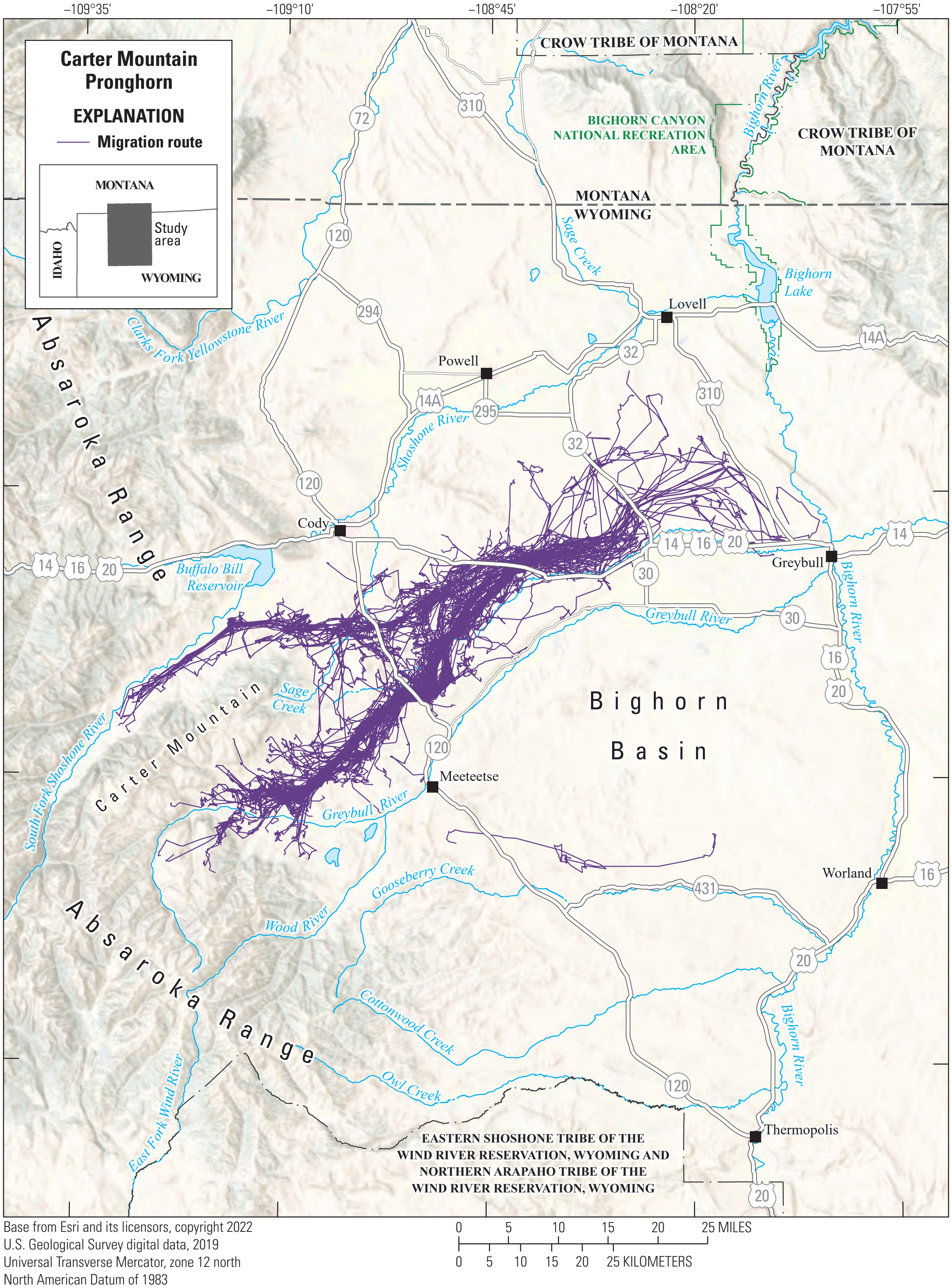

Figure 28. Migration routes of the Carter Mountain pronghorn herd.

Wyoming | Pronghorn

Carter Mountain Pronghorn

The Carter Mountain pronghorn herd contains approximately 7,000 pronghorn—half which migrate 10–60 mi (16–97 km) west from common winter ranges in the Bighorn Basin to summer ranges near the Absaroka Range (fig. 28). During this migration, pronghorn must cross U.S. Highway 14 and Wyoming Highway 120. Most pronghorn summer in ranges west of Wyoming Highway 120 along the Greybull River, but some pronghorn summer in the South Fork Shoshone River drainage. Some of the herd gains nearly 6,000 ft (1,829 m) in elevation to summer on the high plateaus of the Absaroka Range and upper Greybull River and at 10,000–11,000 ft (3,048–3,353 m) above sea level in alpine meadows they share with *Ursus arctos* (grizzly bear) and *Canis lupus* (wolf) populations. Challenges to this herd's migration include multiple highway and fence crossings. Habitat loss and fragmentation from residential development are also a concern.

Animal Capture and Data Collection

Sample size: 128 adult female pronghorn
Relocation frequency: Approximately 2 hours
Project duration: 2019–21

Data Analysis

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

Models derived from:

- Migration: 180 sequences from 58 individuals (91 spring sequences, 89 fall sequences)

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: March 13 to April 3
- Fall: October 8 to October 18

Number of days migrating (mean):

- Spring: 20 days
- Fall: 10 days

Migration corridor length:

- Minimum: 10 mi (16 km)
- Mean: 25 mi (40 km)
- Maximum: 60 mi (97 km)

Other Information

Project contacts:

- Corey Class (corey.class@wyo.gov), Cody Wildlife Management Coordinator, Wyoming Game and Fish Department
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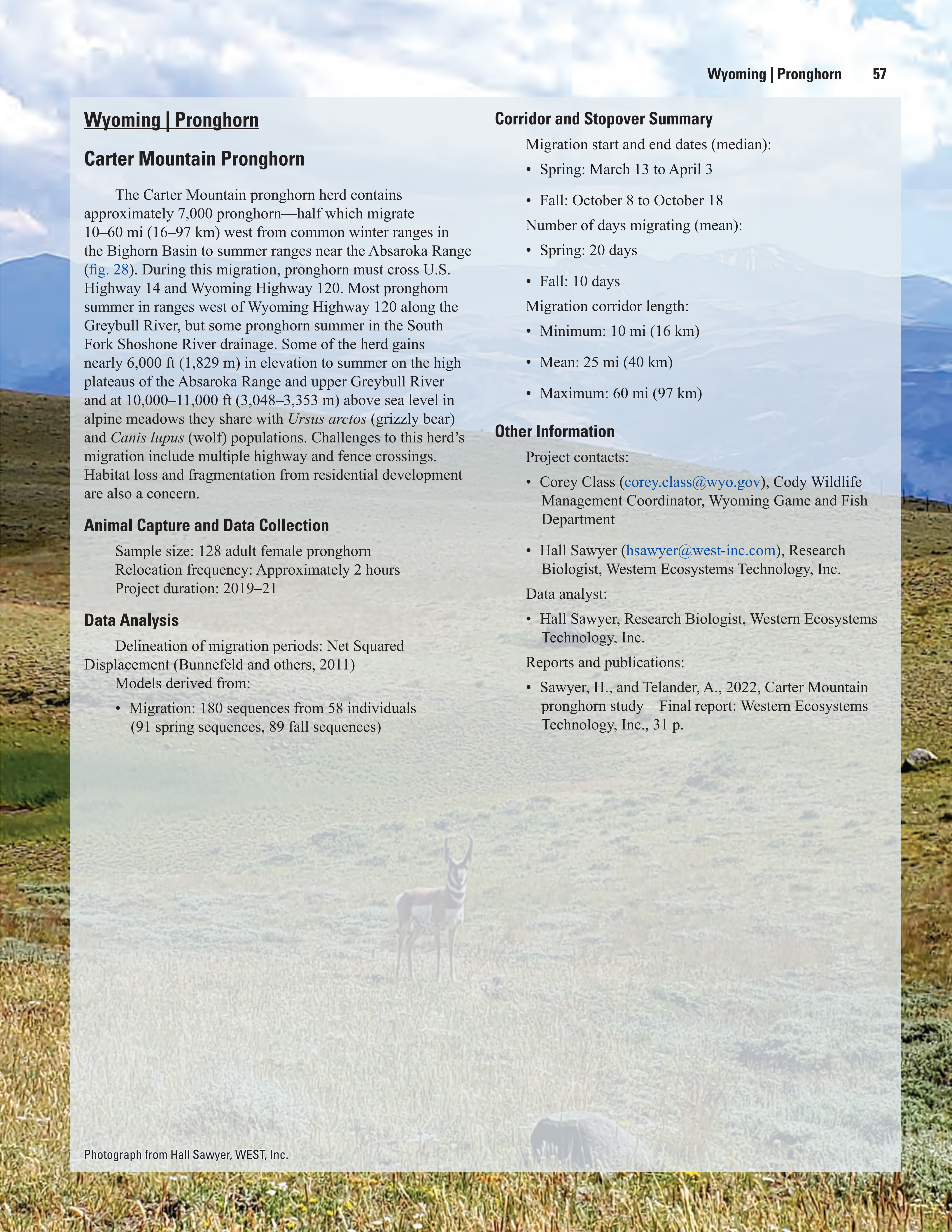
Data analyst:

- Hall Sawyer, Research Biologist, Western Ecosystems Technology, Inc.

Reports and publications:

- Sawyer, H., and Telander, A., 2022, Carter Mountain pronghorn study—Final report: Western Ecosystems Technology, Inc., 31 p.



Photograph from Hall Sawyer, WEST, Inc.

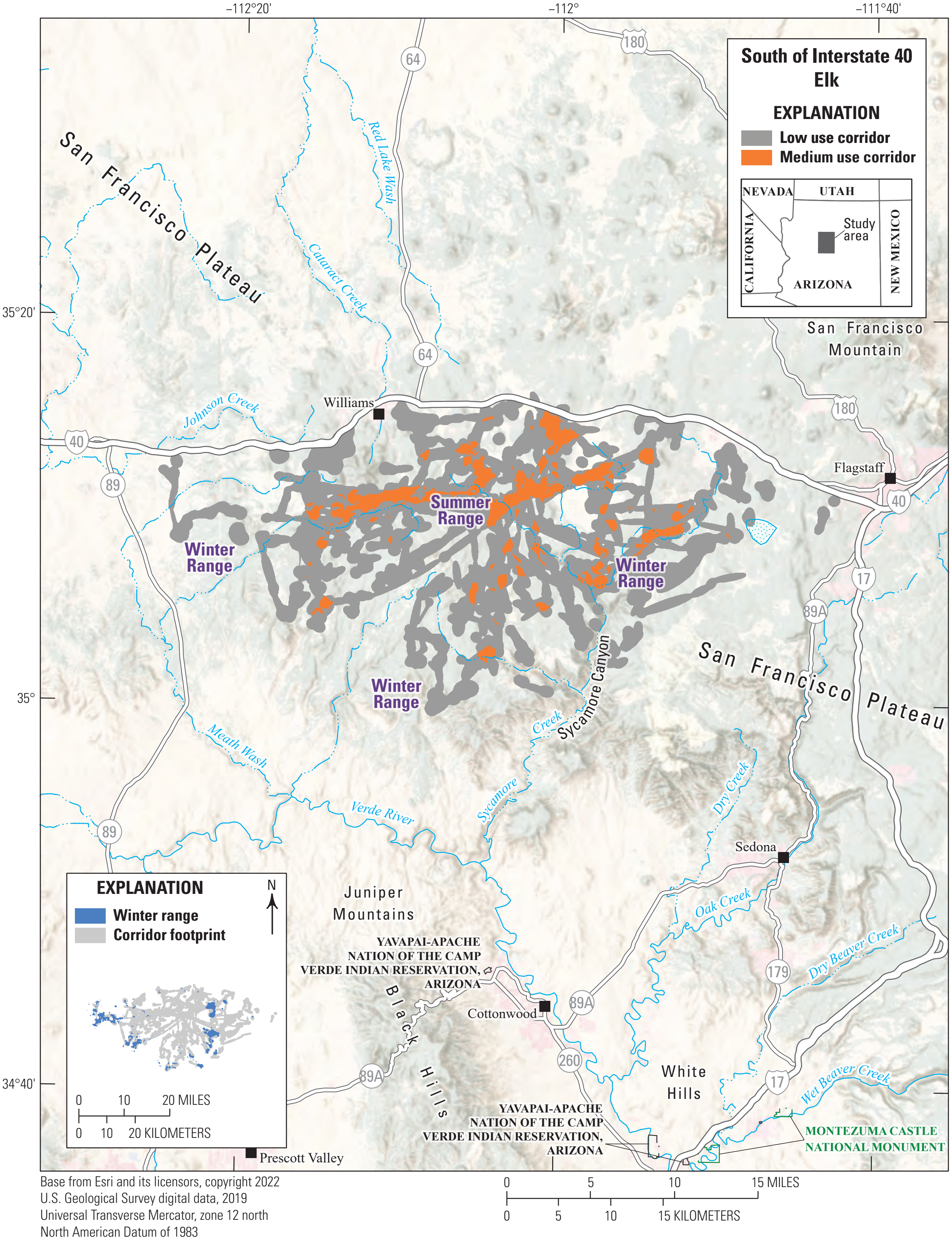


Figure 29. Migration corridors, summer range, and winter ranges of the South of Interstate 40 elk herd.

Arizona | Elk

South of Interstate 40 Elk

The South of Interstate 40 elk herd primarily resides in Arizona Game Management Unit 8. Population surveys in 2021 estimated approximately 4,000 elk inhabited Game Management Unit 8. The elk herd's summer range is primarily characterized by high-elevation ponderosa pine forests and grasslands. The elk migrate from various origin points in their summer range to their winter range, which comprises canyon rims in the area (fig. 29). This series of canyons creates an impermeable southern boundary for this herd. Their winter range along the canyon rim area is primarily characterized by pinyon-juniper, *Arctostaphylos* spp. (manzanita), and *Quercus ilicifolia* (bear oak). Interstate 40 is the primary threat to this herd's migration corridor, which limits habitat connectivity and highway permeability between the South and North of Interstate 40 elk herds (Arizona Game and Fish Department, 2021; Kauffman and others, 2022a). Successful elk crossings of Interstate 40 are rare, and more than 65 WVC occur in this area per year (Arizona Game and Fish Department, 2021). To help mitigate this issue, an overpass is being planned, which could potentially connect these two herds across Interstate 40.

Animal Capture and Data Collection

Sample size: 23 adult elk (5 males, 18 females), 2 juvenile female elk

Relocation frequency: Approximately 2 hours

Project duration: 2009–11 and 2020–present (data through December 2022 analyzed for this report)

Data Analysis

Corridor, stopover, and winter range analysis: Fixed Motion Variance (refer to app. 1 for further description)

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

Models derived from:

- Migration: 71 sequences from 25 individuals (34 spring sequences, 37 fall sequences)
- Winter: 39 sequences from 25 individuals

Migration use classifications:

- Low: Used by at least one individual
- Medium: Used by 10–20 percent of the individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: April 5 to April 13
- Fall: November 30 to December 10

Number of days migrating (mean):

- Spring: 8 days
- Fall: 9 days

Migration corridor length:

- Minimum: 6.14 mi (9.88 km)
- Mean: 19.30 mi (31.06 km)
- Maximum: 51.35 mi (82.64 km)

Migration corridor area:

- Low use: 159,927 acres (64,720 ha)
- Medium use: 18,813 acres (7,614 ha)

Winter Range Summary

Winter start and end dates (median):

- December 10 to April 5
- Winter length (mean): 101 days
- Winter range area: 18,587 acres (7,522 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:

- Haley Nelson, Senior Research Biologist, Arizona Game and Fish Department

Reports and publications:

- Arizona Game and Fish Department, 2020, Arizona State action plan: Phoenix, Ariz., Arizona Game and Fish Department, 57 p. [Also available at https://www.nfwf.org/sites/default/files/2022-09/arizona-action-plan.pdf.]
- Arizona Game and Fish Department, 2021, Research report on elk movements associated with Interstate 40: Phoenix, Ariz., Arizona Department of Transportation, prepared by Arizona Game and Fish Department, project no. NH 040-C(211)S 40 CN 183 H758601L, 118 p.

Photograph from Scott Sprague, Arizona Game and Fish Department.

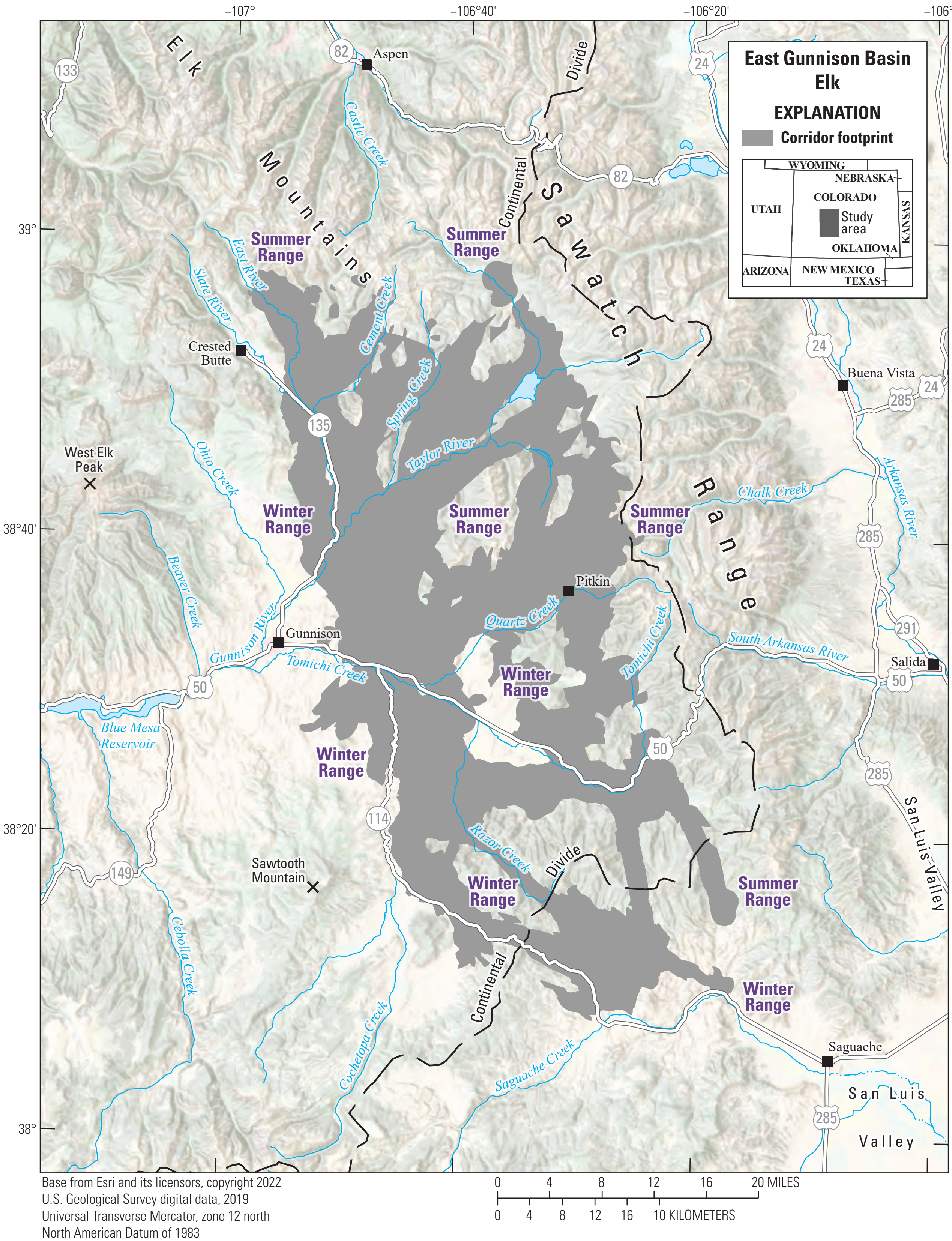


Figure 30. Migration footprint, summer ranges, and winter ranges of the East Gunnison Basin elk herd.

Colorado | Elk

East Gunnison Basin Elk

The East Gunnison Basin elk herd (Data Analysis Unit E43) inhabits the central part of southwest Colorado and overlaps with the Taylor Park mule deer herd (refer to the “Taylor Park Mule Deer” section in this report). The area encompasses approximately 1,432 mi^2 (3,709 km^2) and is bound on the north by the Elk Mountains and Sawatch Range; on the east and south by the Continental Divide; and on the west by the East River, Gunnison River, and Cochetopa Creek (fig. 30). Elevations in the East Gunnison Basin unit range from approximately 7,700 ft (2,347 m) near Gunnison, Colorado, to more than 14,000 ft (4,267 m) along the Continental Divide. The area comprises a mix of land ownership and approximately 88 percent public lands. Most of the private lands are at lower elevations. Historically, the East Gunnison Basin elk herd ranged from 4,000 to 8,000 animals and is currently estimated at 6,900 elk.

During the winters of 2015–22, GPS collars were deployed on 74 adult female elk with the goal of measuring long-term changes in elk distribution patterns and annual survival rates. In general, the GPS-collar data revealed elk seasonally migrate 30–40 mi (48–64 km) in midfall (November) from the highest elevations on the northern and eastern fringes of the unit to the lower elevation winter ranges (approximately 8,000–9,000 ft [2,438–2,743 m] in elevation). The data revealed 20–40 percent of the herd migrates from their typical winter range midwinter (December to February), moving southeast (10–30 mi [16–48 km]), and crossing the Continental Divide (peaking at approximately 10,000–11,000 ft [3,048–3,352 m] in elevation) to finish wintering in areas with less snowpack in the San Luis Valley on the eastern slope of the Continental Divide. The proportion of the herd making this midwinter migration appears to depend on winter conditions in their typical winter range, with approximately 50–70 percent leaving during the years with deeper snowpack. Elk survival declines substantially in these harsh winters, emphasizing the importance of maintaining their ability to move to milder conditions, such as those conditions found across the Continental Divide. The elk making the longest migrations use a network of 3–4 corridors at least 74 mi (119 km) long, which cross U.S. Highway 50, State Route 114, and the dense forests and deeper snowpack along the Continental Divide. State Route 135, which parallels the Gunnison River and East River on the northwestern border of the East Gunnison Basin unit, creates a significant barrier to neighboring elk in the West Elk Mountains unit. However, an estimated 500–750 elk (depending on the conditions) move between the two units by using historically known sites across the river and paralleling the highway. Many of the same corridors and pinch points used by the East Gunnison Basin elk herd overlap the Taylor Park mule deer herd.

Animal Capture and Data Collection

Sample size: 74 adult female elk

Relocation frequency: 13 hours

Project duration: 2015–present (data through December 2021 analyzed for this report)

Data Analysis

Corridor analysis: Fixed Motion Variance (refer to app. 1 for further description)

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

Models derived from:

- Migration: 301 sequences from 60 individuals (165 spring sequences, 136 fall sequences)

Migration use classifications:

- Overall footprint: Any migration area used by greater than or equal to 10 percent of the individuals

Corridor Summary

Migration start and end dates (median):

- Spring: April 24 to May 13
- Fall: November 3 to November 15

Number of days migrating (mean):

- Spring: 25 days
- Fall: 33 days

Migration corridor length:

- Minimum: 5.36 mi (8.62 km)
- Mean: 22.60 mi (36.37 km)
- Maximum: 74.99 mi (102.68 km)

Migration corridor area:

- Overall footprint: 587,092 acres (237,588 ha)

Other Information

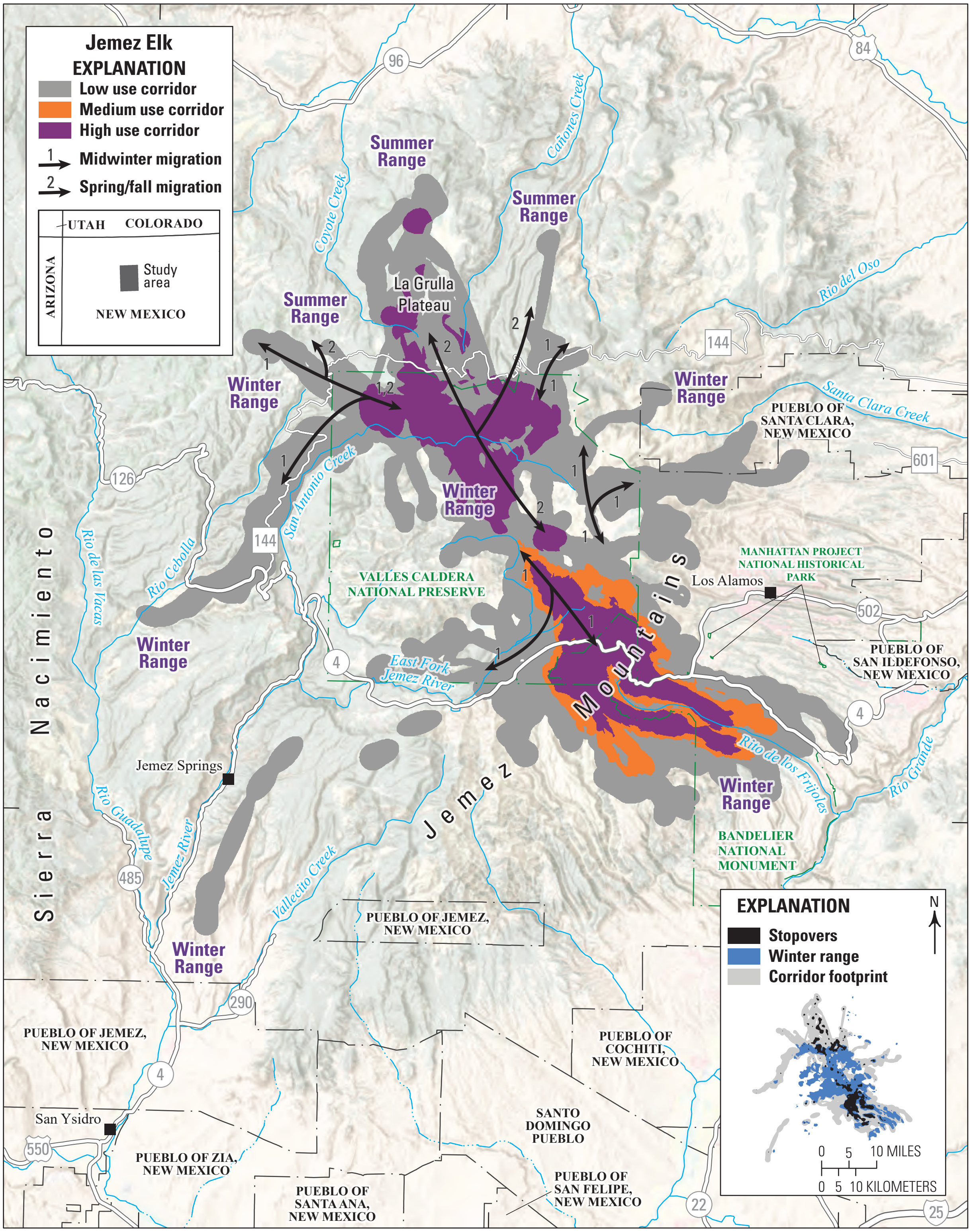
Project contacts:

- Kevin Blecha (kevin.blecha@state.co.us), Wildlife Biologist, Colorado Parks and Wildlife
- Andy Holland (andy.holland@state.co.us), Big Game Manager, Colorado Parks and Wildlife

Data analysts:

- Chloe Beaupre, Graduate Research Assistant, Western Colorado University, Clark School of Environment and Sustainability
- Michelle Cowardin, Wildlife Movement Coordinator, Colorado Parks and Wildlife
- Michelle Flenner, GIS Specialist, Colorado Parks and Wildlife

Photograph from Kevin Blecha and Jeremiah Rummel, Colorado Parks and Wildlife.



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

Figure 31. Migration corridors, stopovers, summer ranges, and winter ranges of the Jemez elk herd.

New Mexico | Elk

Jemez Elk

The Jemez elk herd primarily resides in the Jemez Mountains in the Valles Caldera National Preserve (fig. 31). The herd was originally included in Kauffman and others (2022a) but has been updated for this report because of new GPS-collar data available from 40 additional adult females. The Jemez elk are only partially migratory; some residents remain year round in the Valles Caldera National Preserve and others exhibit two distinct seasonal movement patterns. The first movement pattern occurs during midwinter (January–February) when numerous elk move to the lower elevation slopes of the Valles Caldera National Preserve, primarily southeast towards Bandelier National Monument. The second movement is more typical of a spring and fall migratory movement; elk migrate north to La Grulla Plateau for the summer and return to the Valles Caldera National Preserve for the winter. The primary challenge for migrants is crossing State Route 4 when traveling to Bandelier National Monument.

Animal Capture and Data Collection

Sample size: 122 adult female mule deer

Relocation frequency: Approximately 3–6 hours

Project duration: 2012–18 and 2021–present (data through January 2023 analyzed for this report)

Data Analysis

Corridor, stopover, and winter range analysis: Fixed Motion Variance (refer to app. 1 for further description)

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

Models derived from:

- Migration (midwinter): 179 sequences from 64 individuals (93 early midwinter sequences, 86 late midwinter sequences)
- Migration (Spring and Fall): 31 sequences from 12 individuals (15 spring sequences, 16 fall sequences)
- Winter: 251 sequences from 117 individuals

Migration use classifications:

- Low: Used by at least one individual
- Medium: Used by 10–20 percent of the individuals
- High: Used by >20 percent of the individuals

Corridor and Stopover Summary (Midwinter)

Migration start and end dates (median):

- Early midwinter: December 13 to January 30
- Late midwinter: February 23 to March 1

Number of days migrating (mean):

- Early midwinter: 9 days
- Late midwinter: 6 days

Migration corridor length:

- Minimum: 0.78 mi (1.25 km)
- Mean: 6.51 mi (10.48 km)
- Maximum: 14.22 mi (22.89 km)

Migration corridor area:

- Low use: 105,196 acres (42,571 ha)
- Medium use: 25,022 acres (10,126 ha)
- High use: 14,697 acres (5,948 ha)
- Stopover area: 11,382 acres (4,606 ha)

Corridor and Stopover Summary (Spring and Fall)

Migration start and end dates (median):

- Spring: April 15 to April 16
- Fall: August 16 to August 22

Number of days migrating (mean):

- Spring: 7 days
- Fall: 6 days

Migration corridor length:

- Minimum: 2.65 mi (4.26 km)
- Mean: 7.64 mi (12.29 km)
- Maximum: 17.95 mi (28.89 km)

Migration corridor area:

- Low use: 62,125 acres (25,141 ha)
- High use: 18,790 acres (7,604 ha)
- Stopover area: 6,831 acres (2,765 ha)

Winter Range Summary

Winter start and end dates (median):

- December 1 to February 28
- Winter length (mean): 90 days
- Winter range area: 69,686 acres (28,201 ha)

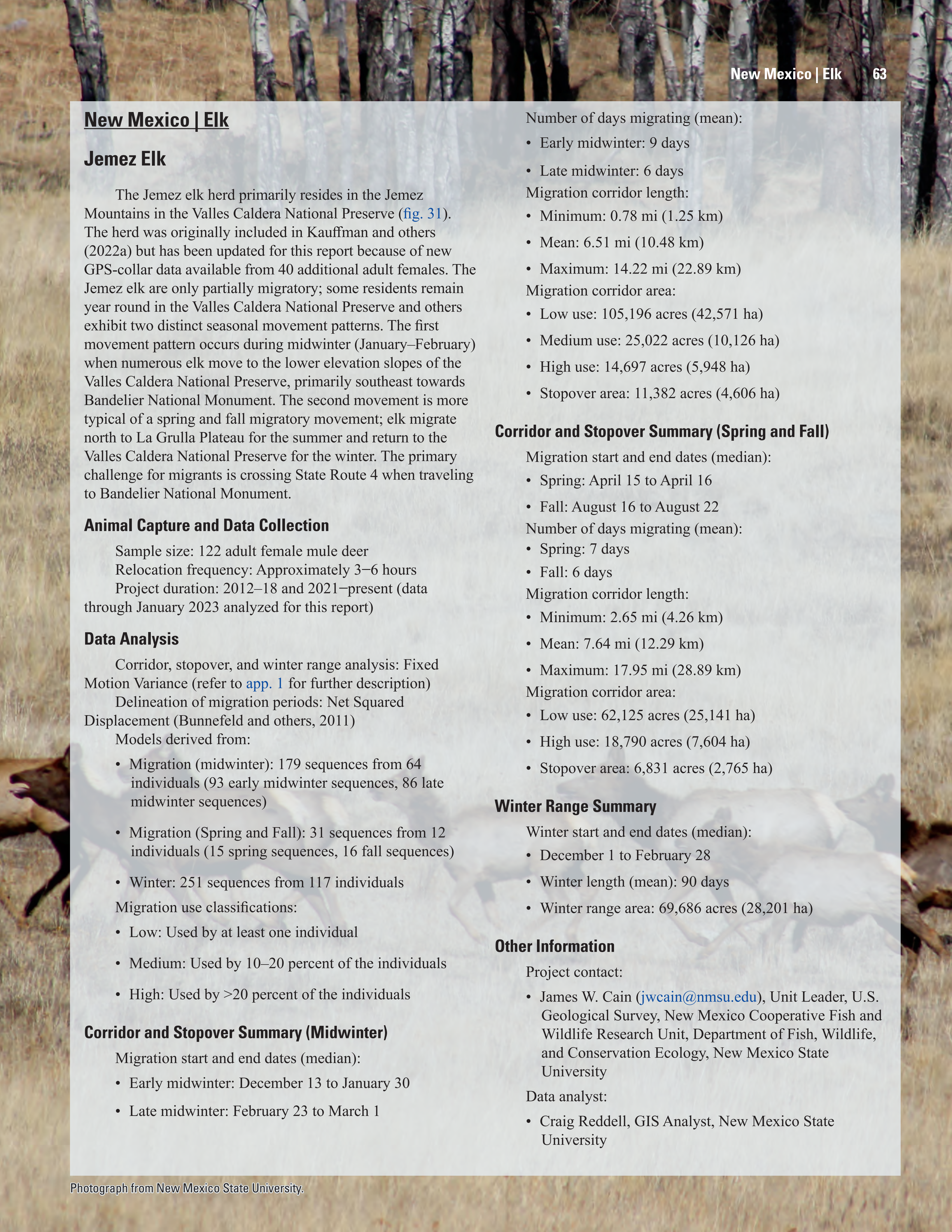
Other Information

Project contact:

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

Data analyst:

- Craig Reddell, GIS Analyst, New Mexico State University



Photograph from New Mexico State University.

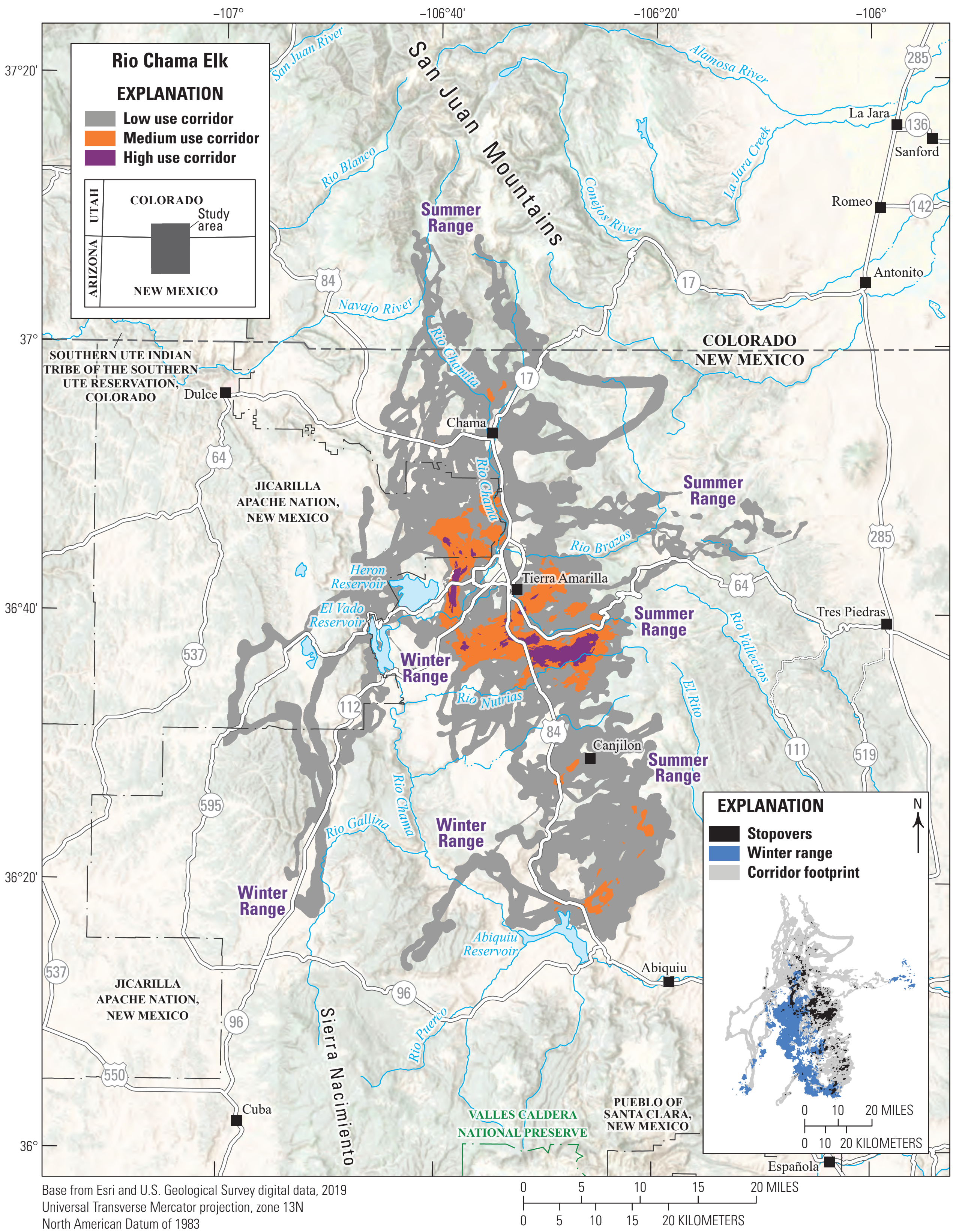


Figure 32. Migration corridors, stopovers, summer ranges, and winter ranges of the Rio Chama elk herd.

New Mexico | Elk

Rio Chama Elk

The Rio Chama elk herd inhabits north-central New Mexico, near Tierra Amarilla (fig. 32). This herd's winter range is predominately west of U.S. Highway 84 between the Heron and Abiquiu Reservoirs. The Rio Chama elk herd migrates through a mosaic of private, public, and Jicarilla Apache Nation, New Mexico lands, using three primary migration corridors: the northern and eastern corridors near Heron Reservoir and the northeastern corridor near Abiquiu Reservoir. Elk using the northern corridor near Heron Reservoir follow a variety of routes; some elk only migrate approximately 6 mi (9.7 km) to summer along the Rio Chama and other elk migrate more than 30 mi (48.3 km) to southern Colorado. The eastern migration corridors are approximately 10 mi (16.1 km) and cross U.S. Highways 84 and 64 south of Tierra Amarilla before settling in the western San Juan Mountains. Elk near the Abiquiu Reservoir commonly migrate northeast and cross State Route 84 into the San Juan Mountains to their summer range southeast of Canjilon, New Mexico. The herd faces several challenges, such as crossing State Route 112 and U.S. Highways 84 and 64, increasing density of housing subdivisions in some areas along their migration, and fencing, especially taller fencing that elk cannot jump.

Animal Capture and Data Collection

Sample size: 62 adult female elk
Relocation frequency: Approximately 2 hours
Project duration: 2021–present (data through December 2022 analyzed for this report)

Data Analysis

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

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

Models derived from:

- Migration: 174 sequences from 50 individuals (94 spring sequences, 80 fall sequences)
- Winter: 44 sequences from 44 individuals

Migration use classifications:

- Low: Used by at least one individual
- Medium: Used by 10–20 percent of the individuals
- High: Used by >20 percent of the individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: April 26 to May 6
- Fall: November 4 to November 9

Number of days migrating (mean):

- Spring: 16 days
- Fall: 14 days

Migration corridor length:

- Minimum: 2.50 mi (4.02 km)
- Mean: 12.94 mi (20.83 km)
- Maximum: 43.35 mi (69.76 km)

Migration corridor area:

- Low use: 521,293 acres (210,960 ha)
- Medium use: 58,592 acres (23,711 ha)
- High use: 9,494 acres (3,842 ha)
- Stopover area: 55,538 acres (22,475 ha)

Winter Range Summary

Winter start and end dates (median):

- November 9 to April 28
- Winter length (mean): 185 days
- Winter range area: 163,843 acres (66,305 ha)

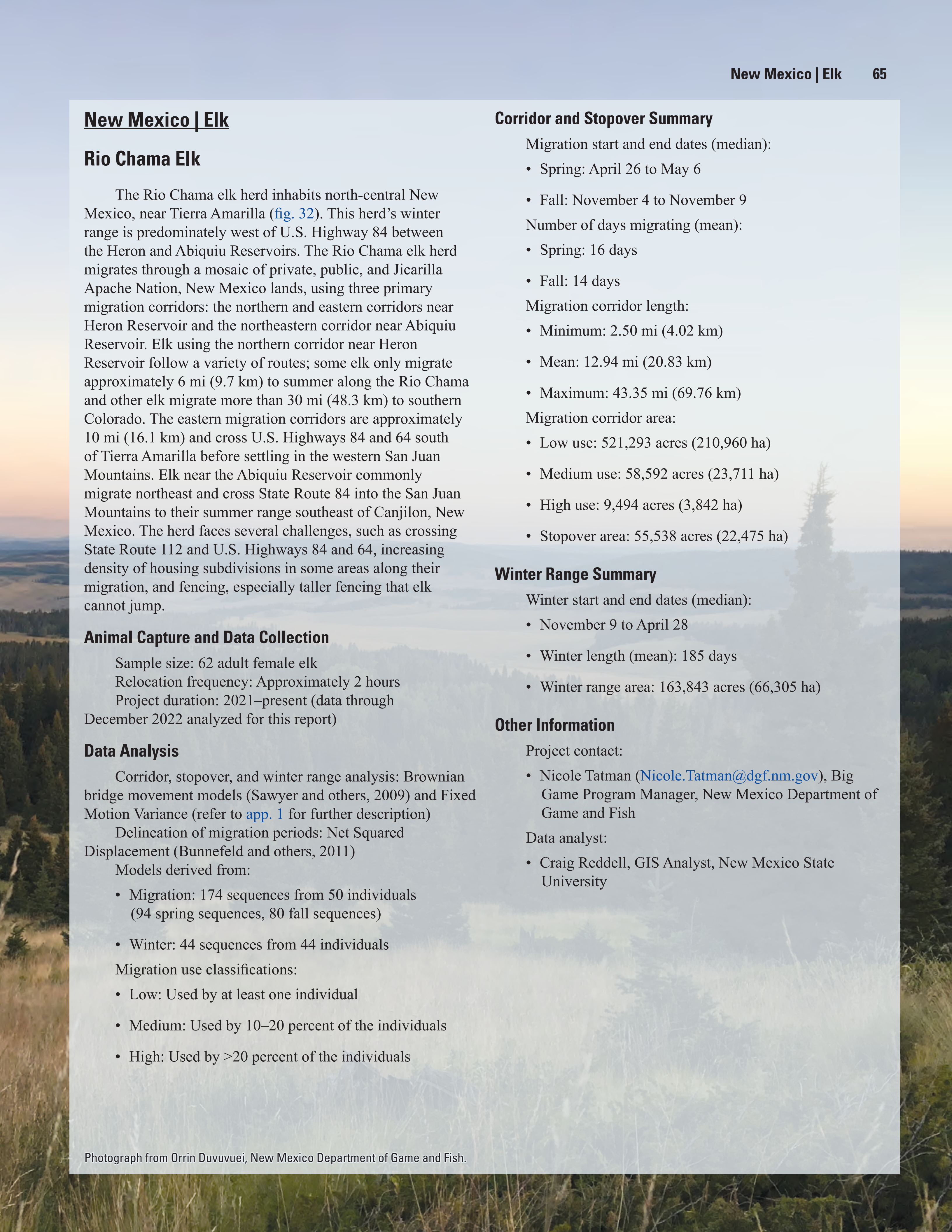
Other Information

Project contact:

- Nicole Tatman (Nicole.Tatman@dgf.nm.gov), Big Game Program Manager, New Mexico Department of Game and Fish

Data analyst:

- Craig Reddell, GIS Analyst, New Mexico State University



Photograph from Orrin Duvuvuei, New Mexico Department of Game and Fish.

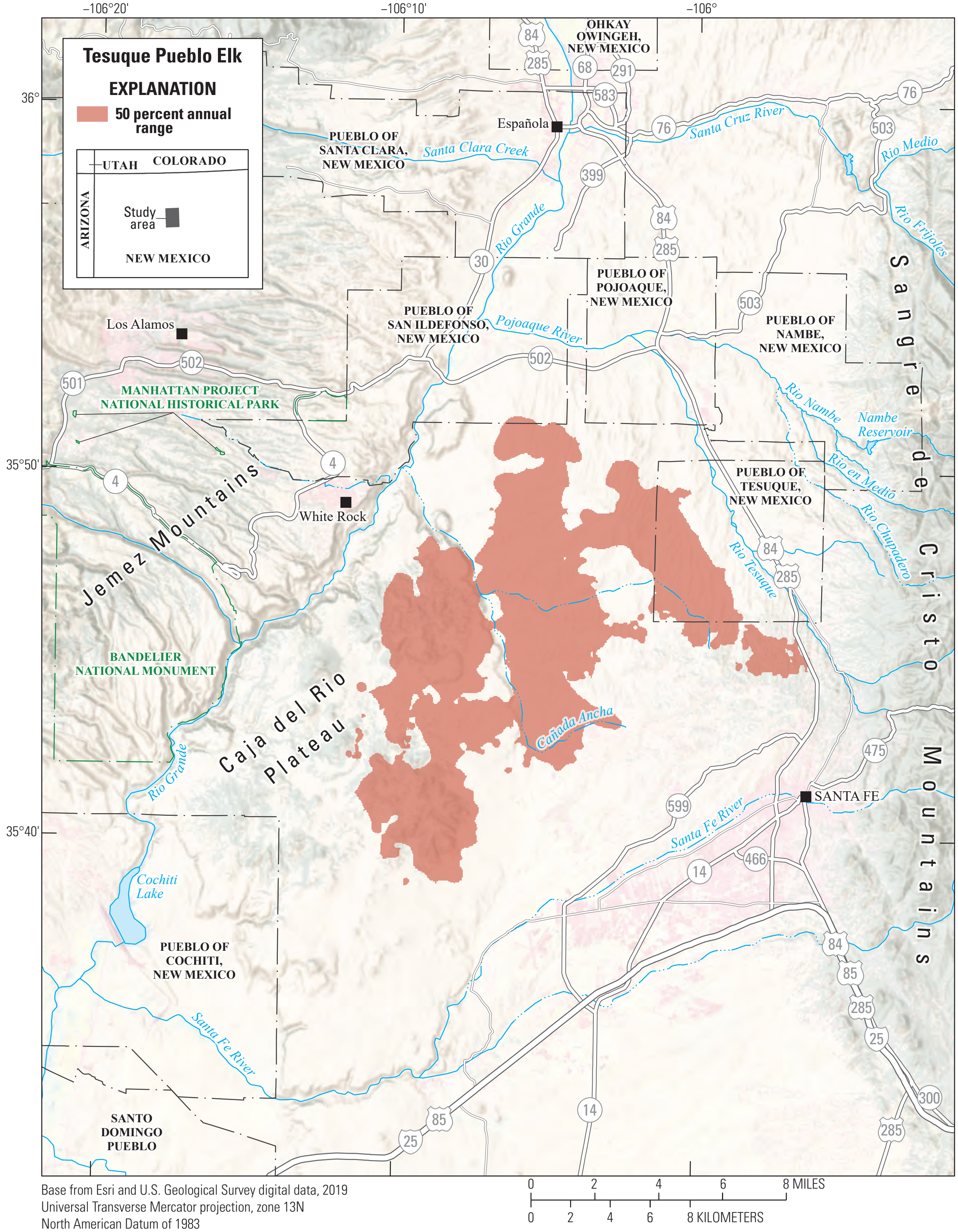


Figure 33. Annual range of the Tesuque Pueblo elk herd.

New Mexico | Elk

Tesuque Pueblo Elk

The Tesuque Pueblo elk herd is primarily nonmigratory. The elk in this herd came to the region in the late 1990s and early 2000s, likely because of displacement by large fires in the Jemez Mountains. U.S. Highways 84 and 285 bisect Pueblo of Tesuque, New Mexico, and create a physical barrier for elk movement, which contributes to potential WVC. GPS collars were deployed on two female elk to track the habitat and lands used by this herd. The elk seasonally use the western section of Pueblo of Tesuque, New Mexico (fig. 33). Similar to the Tesuque Pueblo mule deer herd (refer to the "Tesuque Pueblo Mule Deer" section of this report), the annual range (fig. 33) of the Tesuque Pueblo elk herd primarily consists of pinyon-juniper woodlands and pinyon-juniper savannah. The elk use the southwest area of Pueblo of Tesuque, New Mexico, and private lands southwest of the reservation. The herd also uses BLM and FS lands adjacent to Pueblo of Tesuque, New Mexico, in the Caja del Rio Plateau. A lower elevation and drier section of the FS lands, the Caja del Rio Plateau is a pinyon-juniper-dominated vegetation zone with areas of sage and mixed grasses. The elk are culturally significant to Pueblo of Tesuque, New Mexico, Tribal members.

Animal Capture and Data Collection

Sample size: 2 adult female elk
Relocation frequency: Approximately 1–4 hours
Project duration: 2012–15

Data Analysis

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

Models derived from:

- Annual range: 6 sequences from 2 individuals

Annual Use Summary

- Annual range (50 percent contour) area: 46,668 acres (18,886 ha)

Other Information

Project contact:

- Patrick Ryan Swazo-Hinds (rswazohinds@puebloofesuque.org), Environmental Biologist, Pueblo of Tesuque Department of Environment and Natural Resources

Data analyst:

- Hall Sawyer, Research Biologist, Western Ecosystems Technology, Inc.

Photograph from Tesuque Pueblo Department of Environment and Natural Resources.

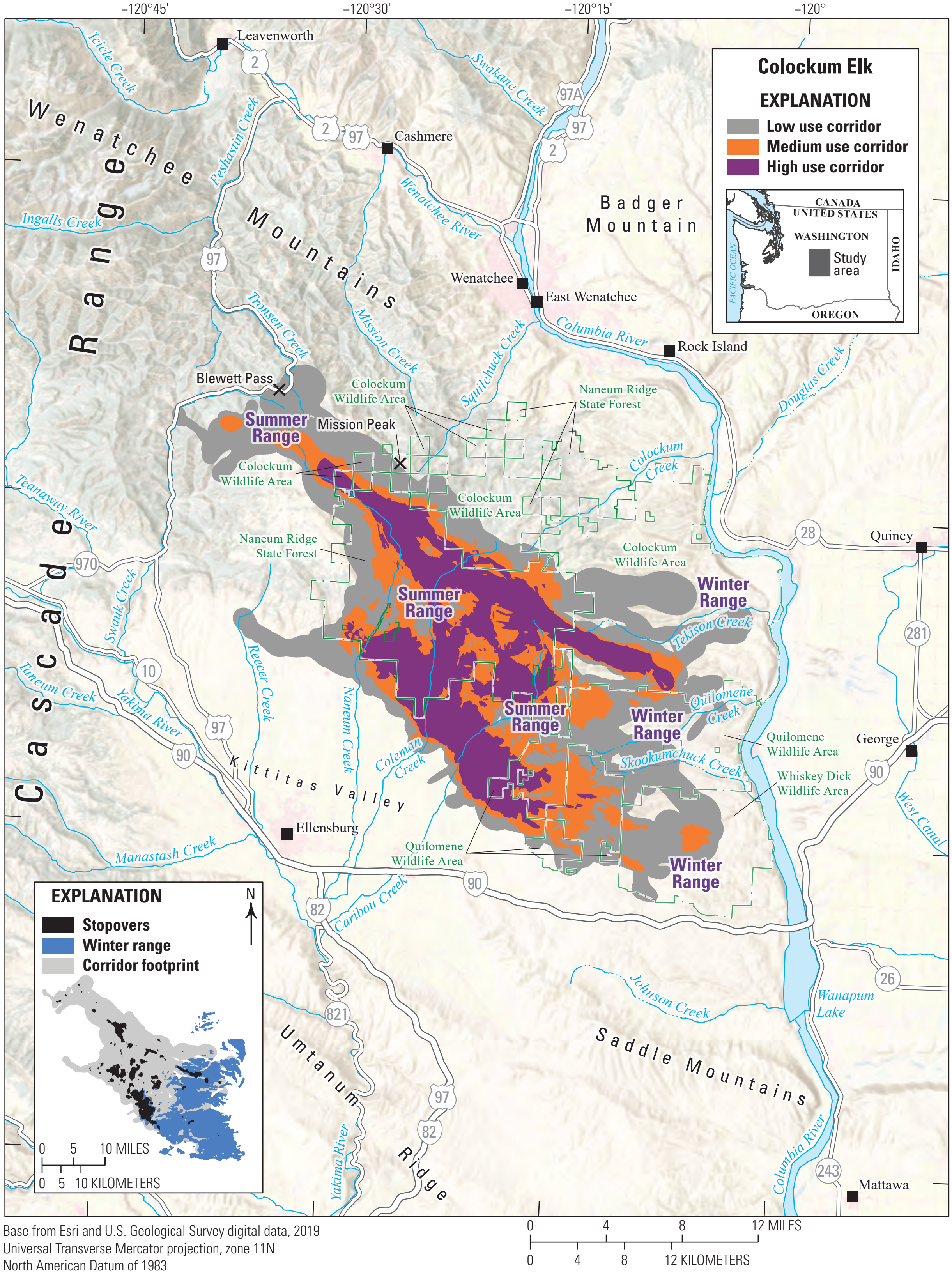


Figure 34. Migration corridors, stopovers, summer ranges, and winter ranges of the Colockum elk herd.

Washington | Elk

Colockum Elk

The Colockum elk herd inhabits a mix of public and private lands northeast of Ellensburg, Washington, between Blewett Pass of the Cascade Range and west of the Columbia River (fig. 34). The herd size ranges between 4,000 and 5,000 elk and is partially migratory; the herd includes a mix of resident (63 percent of GPS-collared elk) and migratory (34 percent of GPS-collared elk) behaviors. During winter, many elk inhabit grassland, sagebrush, antelope bitterbrush, and ponderosa pine habitats in the Whiskey Dick, Quilomene, and Colockum Wildlife Areas and the eastern reaches of the Naneum Ridge State Forest. As spring green up of vegetation nears, migratory elk travel northwest toward summer ranges in the Wenatchee Mountains, north of Ellensburg, Washington. Resident elk inhabit the same areas as wintering migratory elk. Agricultural producers in the eastern Kittitas Valley often experience conflicts with elk consuming hay in fields. Additional concerns for the herd include semipermeable barriers along Interstate 90 and U.S. Highway 97 and disturbance from human recreation on the winter range.

Animal Capture and Data Collection

Sample size: 99 adult female elk
Relocation frequency: Approximately 3 hours
Project duration: 2009–12

Data Analysis

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

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

Models derived from:

- Migration: 89 sequences from 35 individuals (49 spring sequences, 40 fall sequences)
- Winter: 138 sequences from 77 individuals

Migration use classifications:

- Low: Used by at least one individual
- Medium: Used by 10–20 percent of the individuals
- High: Used by >20 percent of the individuals

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: April 21 to May 3
- Fall: November 11 to November 20

Number of days migrating (mean):

- Spring: 14 days
- Fall: 8 days

Migration corridor length:

- Minimum: 0.88 mi (1.41 km)
- Mean: 15.62 mi (25.13 km)
- Maximum: 27.47 mi (44.21 km)

Migration corridor area:

- Low use: 204,217 acres (82,644 ha)
- Medium use: 100,161 acres (40,534 ha)
- High use: 54,327 acres (21,985 ha)
- Stopover area: 20,964 acres (8,484 ha)

Winter Range Summary

Winter start and end dates (median):

- November 20 to April 23
- Winter length (mean): 151 days
- Winter range area: 97,765 acres (39,564 ha)

Other Information

Project contacts:

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- William Moore (william.moore@dfw.wa.gov), Ungulate Specialist, Washington Department of Fish and Wildlife
- Erin Wampole (erin.wampole@dfw.wa.gov), Assistant District Wildlife Biologist, Washington Department of Fish and Wildlife

Data analyst:

- Brendan Oates, Ungulate Specialist, Washington Department of Fish and Wildlife

Photograph from Pete Lopushinsky, Washington Department of Fish and Wildlife.

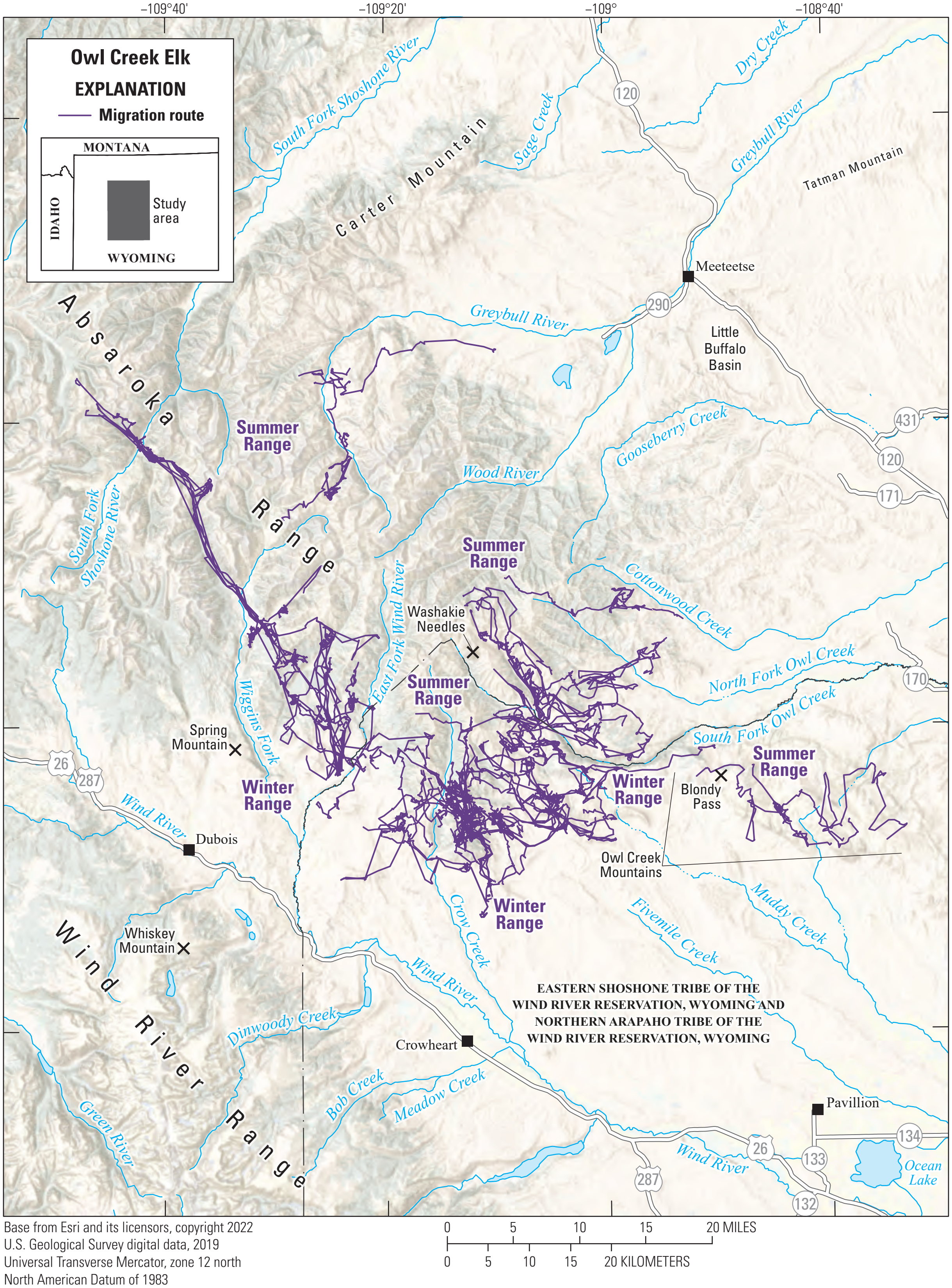

Figure 35. Migration routes, summer ranges, and winter ranges of the Owl Creek elk herd.

Wind River Reservation | Elk

Owl Creek Elk

The Owl Creek elk herd—between 7,500 and 8,500 wintering elk—inhabits the northwest corner of the Wind River Reservation, traversing habitats along the Absaroka Range and the Owl Creek Mountains (fig. 35). The herd contains resident and migratory elk; migrants travel an average 10.7 mi (17.2 km) one way. Elevations range from 6,000 ft (1,829 m) at the Wind River near Crowheart, Wyoming, to 12,200 ft (3,700 m) in the Absaroka Range, and summits in the Owl Creek Mountains, which reach 8,000–9,800 ft (2,438–2,987 m). Habitats range from sage and desert scrub in the lowlands to upland meadows, aspen groves, *Pinus contorta* (lodgepole pine) forests, and alpine tundra. When on the Wind River Reservation, the elk are under the sovereignty of the Eastern Shoshone Tribe of the Wind River Reservation, Wyoming, and Northern Arapaho Tribe of the Wind River Reservation, Wyoming. During spring migration, some elk cross the East Fork Wind River to FS lands. Other migrations are entirely within the reservation, including the upper tributaries near Washakie Needles or the Owl Creek Mountains. Residents in the herd also use the Owl Creek Mountains, particularly the part east of Blondy Pass. Many areas contain significant evidence of past hunting and ceremonial activity, and according to Shoshone ethnography, elk were significant game acquisition in the prereservation era of the 1800s (Shimkin, 1947). This elk herd remains culturally and economically valuable to Tribal members who sustainably harvest elk under a game code established in 1984 (Nickerson, 2019; Wind River Tribal Court, 2004). Habitats are virtually free of human disturbance and development aside from Tribal member livestock grazing and a few Tribal-owned and operated oilfields in the desert winter range. Threats to habitat include drought and climate change or biological invasions of nonnative cheatgrass and feral horses contributing to poor range conditions. In 2022, Tribes started working in partnership with the Bureau of Indian Affairs Wind River Agency, U.S. Fish and Wildlife Service, Wyoming Game and Fish Department, Wyoming Legislature, Wyoming Livestock Board, and the Wild Sheep Foundation to reduce the feral horse population and design projects to restore habitats to greater productivity (Nikonow, 2023).

Animal Capture and Data Collection

Sample size: 32 adult female elk
Relocation frequency: Approximately 1 hour
Project duration: 2018–22

Data Analysis

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

Models derived from:

- Migration: 77 sequences from 16 individuals (40 spring sequences, 37 fall sequences)
- Winter: 55 sequences from 31 individuals

Corridor and Stopover Summary

Migration start and end date (median):

- Spring: May 29 to June 3
- Fall: October 25 to October 27

Number of days migrating (mean):

- Spring: 8 days
- Fall: 8 days

Migration length:

- Minimum: 2.97 mi (4.78 km)
- Mean: 10.71 mi (17.24 km)
- Maximum: 36.70 mi (59.07 km)

Winter Range Summary

Winter start and end dates (median):

- October 28 to May 29
- Winter length (mean): 222 days

Other Information

Project contacts:

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

Data analyst:

- Jennifer McKee, Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology, University of Wyoming

Photograph from Mark Gocke, Wyoming Game and Fish Department.

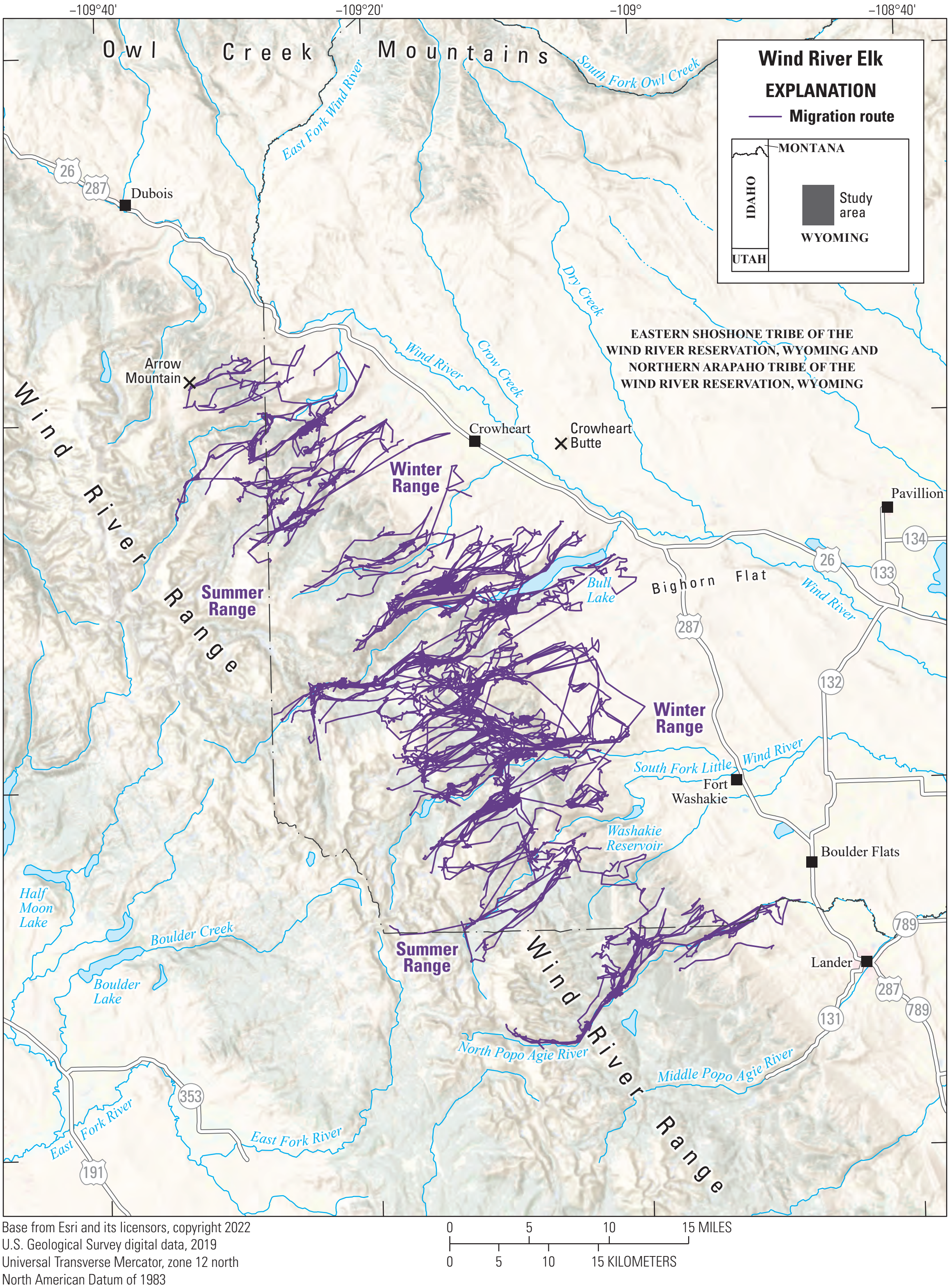

Figure 36. Migration routes, summer ranges, and winter ranges of the Wind River elk herd.

Wind River Reservation | Elk

Wind River Elk

The eastern slope of the Wind River Range provides habitat to approximately 4,000–5,000 migratory elk. The Wind River Elk herd winters on the Wind River Reservation, which is managed under the sovereignty of the Eastern Shoshone Tribe of the Wind River Reservation, Wyoming, and the Northern Arapaho Tribe of the Wind River Reservation, Wyoming (fig. 36). In spring, the herd migrates up in elevation to a roadless area established by the Tribes in the late 1930s—decades before The Wilderness Act of 1964 (Public Law 88–577, 16 U.S.C. 1131–1136)—or to adjacent FS lands. Many of the migration routes are along waterways that have significant cultural heritage, including petroglyphs in the Dinwoody-style and areas connected to stories of sacred figures and occurrences (Wind River Visitors Council, 2022). Elk are a prominent part of ongoing Tribal cultural and language revitalization efforts. Collared elk migrate through historical hunting pits and drive lines used by Native peoples thousands of years ago. The herd is actively hunted by Tribal members per a harvest regulation code (Nickerson, 2019; Wind River Tribal Court, 2004). The terrain ranges from 6,000 ft (1,829 m) to 12,000 ft (3,658 m), but most elk summer at elevations below 11,000 ft (3,353 m). Foothill habitats contain grass and sage, whereas the rocky Wind River Range contains alpine, lodgepole pine forests, mixed grass-conifer basins and ridges, and *Salix* spp. (willow)-lined creeks. The foothills have minimal development, except for irrigation infrastructure at Bull Lake and Washakie Reservoir and fenced ranches near Crowheart, Wyoming. Elk routinely winter in the remote foothills of the Wind River Range and near the more developed areas of Boulder Flats, Fort Washakie, and Lander, Wyoming. However, near Crowheart Butte and Bighorn Flat, groups of elk sometimes cross U.S. Highways 26 and 287 to the north or east, putting them at risk for elk-vehicle mortality.

Animal Capture and Data Collection

Sample size: 34 adult female elk
Relocation frequency: Approximately 1 hour
Project duration: 2018–22

Data Analysis

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

Models derived from:

- Migration: 140 sequences from 30 individuals (75 spring sequences, 65 fall sequences)

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: June 2 to June 7
- Fall: October 11 to October 20

Number of days migrating (mean):

- Spring: 7 days
- Fall: 7 days

Migration corridor length:

- Minimum: 3.68 mi (5.93 km)
- Mean: 9.43 mi (15.17 km)
- Maximum: 19.89 mi (32.01 km)

Winter Range Summary

Winter start and end dates (median):

- October 20 to June 2
- Winter length (mean): 221 days

Other Information

Project contacts:

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

Data analyst:

- Emily Gelzer, Associate Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming

Photograph from Mark Gocke, Wyoming Game and Fish Department.

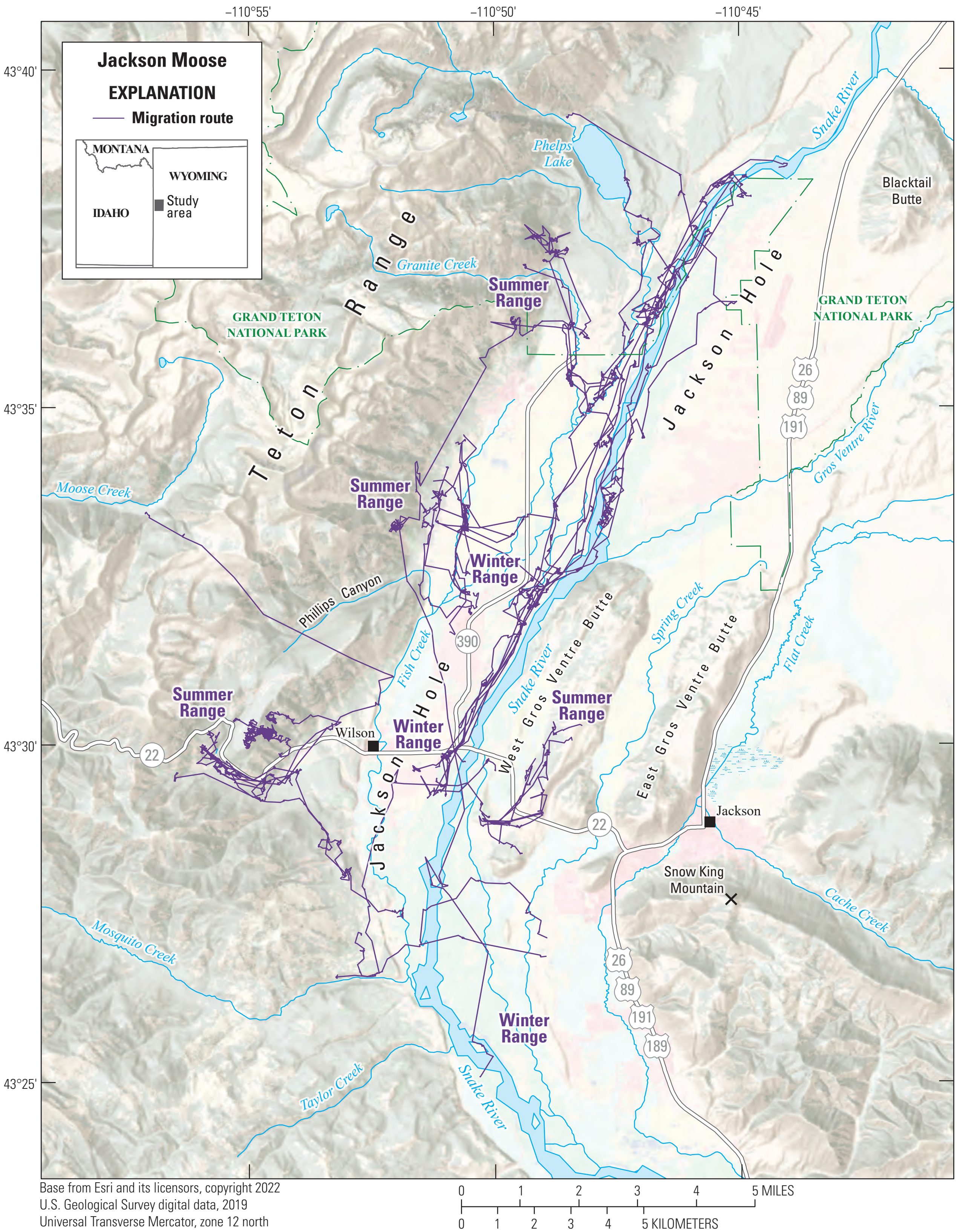

Figure 37. Migration routes, summer ranges, and winter ranges of the Jackson Moose herd.

Wyoming | Moose

Jackson Moose

The Jackson moose herd inhabits an area 2,023 mi^2 (5,239 km^2) northwest of Jackson, Wyoming, in the lowlands of the Snake River. The Jackson moose herd was historically abundant and had a peak of 3,000–5,000 moose in the early 1990s. However, the herd declined significantly following the large counts in the early 1990s and continues to decline with an average count of 280 moose between 2016 and 2020 (Wyoming Game and Fish Department, 2022b). The migrations of the northern portion of the herd were published in Kauffman and others (2020a). The southern portion of the herd, presented here, resides near Wilson, Wyoming, and is partially migratory. Many of the migratory moose move from low-elevation winter ranges along the Snake River to high-elevation summer ranges in the surrounding national forests and Grand Teton National Park (fig. 37). Winter ranges are characterized by riparian, mountain shrub, and aspen communities, and summer ranges include montane meadows and forested habitats. The Snake River corridor serves as a movement pathway between the southern and northern areas and provides an important riparian food resource. Migration distances range from <1 mi (<1 km) to roughly 13 mi (21 km). Despite hunting season closures and a reduction in licenses, this herd has not responded to management changes and continues to be closely monitored by regional wildlife management agencies.

Animal Capture and Data Collection

Sample size: 29 adult female moose
Relocation frequency: Approximately 0.5 hours
Project duration: 2019–22

Data Analysis

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

- Migration: 43 sequences from 14 individuals (27 spring sequences, 16 fall sequences)

Corridor and Stopover Summary

Migration start and end dates (median):

- Spring: April 2 to April 14
- Fall: November 16 to November 27

Number of days migrating (mean):

- Spring: 7 days
- Fall: 5 days

Migration corridor length:

- Minimum: 0.29 mi (0.47 km)
- Mean: 3.79 mi (6.10 km)
- Maximum: 12.82 mi (20.63 km)

Winter Range Summary

Winter start and end dates (median):

- November 27 to April 7
- Winter length (mean): 133 days

Other Information

Project contacts:

- Alyson Courtemanch (alyson.courtemanch@wyo.gov), Wildlife Biologist, Wyoming Game and Fish Department
- Benjamin Wise (benjamin.wise@wyo.gov), Wildlife Disease Biologist, Wyoming Game and Fish Department
- Gary Fralick (gary.fralick@wyo.gov), Wildlife Biologist, Wyoming Game and Fish Department

Data analysts:

- Emily Gelzer, Associate Research Scientist, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming

Photograph from Mark Gocke, Wyoming Game and Fish Department

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Appendix 1. Methods

Corridors and Stopovers

Extracting and Mapping Migration Sequences

To identify spring and fall migration start and end dates for each 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 individual's movement trajectory in the Migration Mapper application (Merkle and others, 2022). The NSD curve represents the square of the straight-line distance between any global positioning system (GPS) location of an animal's movement trajectory and a location in the animal's winter or summer range. Users defined this point separately for each herd based on the start of a biological year, which ranged between January 1 and March 31.

When an animal stays in a defined home range, the NSD varies little during the course of a year. However, when an animal migrates away from its winter range, the NSD of each successive location increases until the animal settles in its summer range (fig. 1.1*A, B, C*). The days with clear breakpoints in the NSD curves represent the start and end dates for migration and were used to identify the sequential GPS locations for spring and fall migration (in other words, the migration sequences). Migration routes were mapped by joining successive GPS locations with a straight line in each migration sequence.

Calculating Probability of Use with Brownian Bridge Movement Models

Once migration sequences were extracted for each individual in a given year, we used a Brownian bridge movement model (BBMM; Horne and others, 2007) to estimate a utilization distribution (UD) representing the probability of use during migration. The UD produced from the BBMM provides a probability surface, or heat map, of the area used in each migration sequence. Additionally, the outer bounds of the UD provide estimated widths of the movement path around the straight line between an animal's two successive locations. Together, the heat map and boundary of the UD can be used to identify migration corridors (Sawyer and others, 2009) and the stopover sites where animals spend extended time foraging along their migration route (Sawyer and Kauffman, 2011).

To generate the heat map for each migration sequence, we used the BBMM to estimate a UD with a grid resolution of 164 feet (50 meters). When GPS collars failed to record a location at a given time and breaks in the sequential data exceeded an 8–14-hour time lag, we did not build a bridge between the two locations encompassing the break. A key parameter of the BBMM is the Brownian motion variance (BMV), which provides an index of the mobility, or speed of movement, of the animal under observation (Horne and others, 2007). An empirical estimate of the BMV was obtained for each migration sequence following the methods of Horne and others (2007). We did not include migration sequences with a BMV greater than or equal to 1.98 acres (8,000 square meters [m^2]) because large BMV values poorly represented the observed migration trajectory.

Variations of the BBMM Method—Sparse Data and Fixed Motion Variance

When location data are sparse (in other words, when there is a long time interval between GPS locations), the BBMM performs poorly because of the increased uncertainty in the movement path between two successive GPS locations. Such uncertainty tends to overestimate the corridor width and area (Horne and others, 2007; Benhamou, 2011). To facilitate corridor analyses of migration sequences collected with low relocations rates (in other words, fix rates), we sometimes used the alternative Fixed Motion Variance method, in which we set the BMV at specific levels when estimating the UDs for each migration sequence (Kauffman and others, 2020; Julien Fattebert, Ecotec Environment, unpub. data, 2023). For herds with sparse sampling data, we set the BMV between 0.15 and 0.40 acres (600 and 1,600 m^2, respectively) for *Cervus canadensis* (elk) and *Antilocapra americana* (pronghorn) and between 0.10 and 0.30 acres (400 and 1,200 m^2, respectively) for *Odocoileus hemionus* (mule deer; Julien Fattebert, Ecotec Environment, unpub. data, 2023).

In most cases, traditional BBMM methods were used to estimate corridors and stopovers. However, when there were significant amounts of missing data in the migration sequences, corridors were calculated using Fixed Motion Variance techniques if they improved delineation as observed through a visual comparison of maps from the two methods. When fix rates were highly variable among individuals in a herd, BBMM and Fixed Motion Variance methods were used to construct individual UDs. In general, by bridging gaps in the probability surface created by missing GPS locations, Fixed Motion Variance provided a modeled corridor that more closely matched data with frequent relocations (for example, a 2-hour fix rate; Julien Fattebert, Ecotec Environment, unpub. data, 2023). In most of these cases, a 14-hour time lag was allowed; a 27-hour or 48-hour time lag was allowed only when it provided more complete migration corridors compared to using a 14-hour time lag.

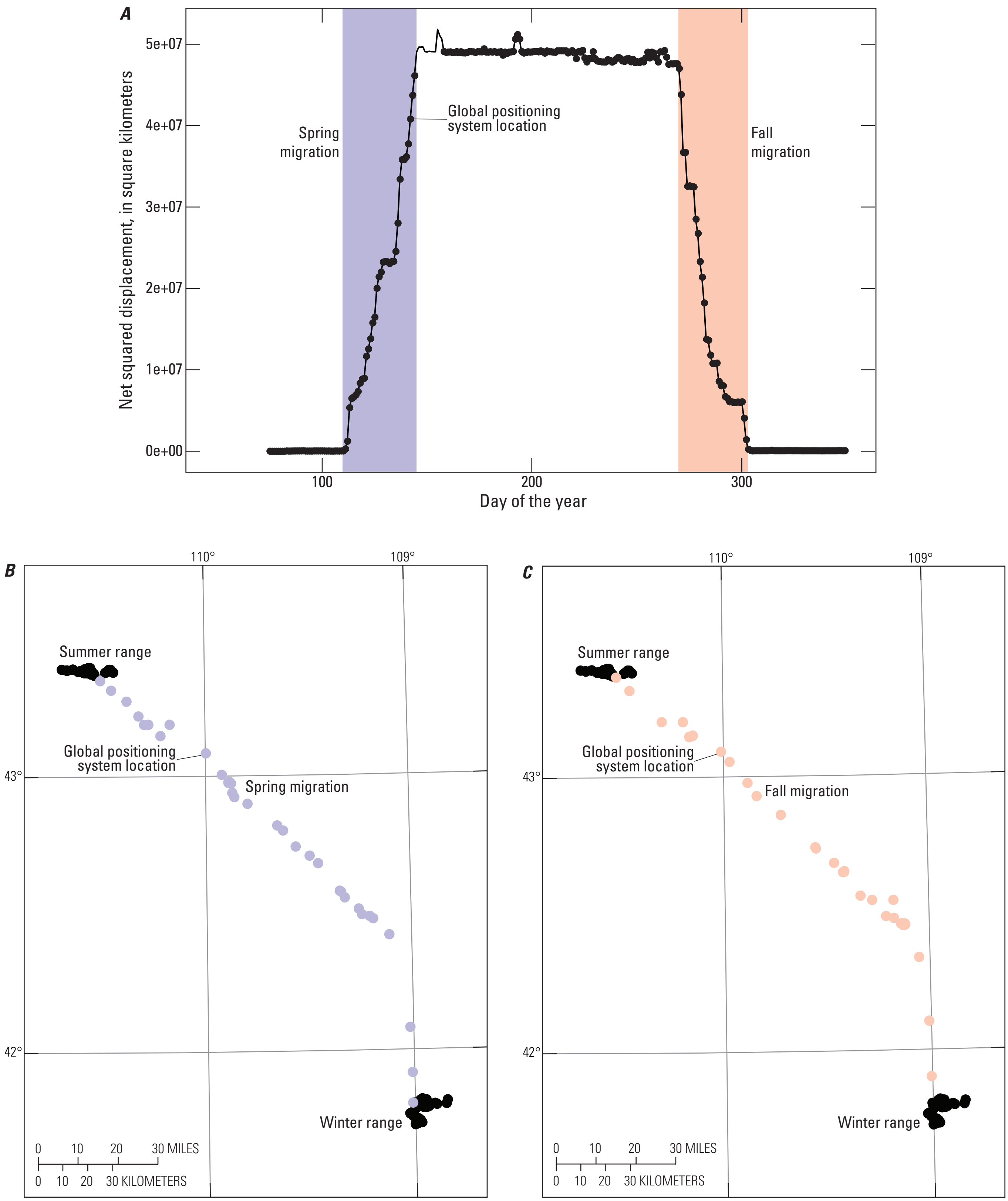

Figure 1.1. Example of Net Squared Displacement (NSD) analysis to identify migration sequences *A,* breakpoints in the NSD curve provide the start and end dates for the spring migration when an animal migrates from the winter range to the summer range; the fall migration is shown when an animal leaves its summer range to return to the winter range; *B,* the corresponding global positioning system (GPS) locations are highlighted on the map insets for the spring migration; *C,* the GPS locations are highlighted on the map insets for the fall migration. For ease of readability, only one GPS location per day is shown. [e+, e-notation]

Calculating Population-Level Corridors and Stopovers

We applied a three-step process to calculate population-level corridors and to identify stopovers; the process generally followed the methods developed by Sawyer and others (2009). First, we averaged the UDs for a given individual's spring and fall migration sequences across all years to produce a single, individual-level migration UD. We rescaled this mean UD to sum to one. Second, we defined a migration footprint for each individual as the 99-percent isopleth of its UD. We then stacked all the individual footprints for a given population, which provided a raster representing the number of animals that used each grid cell during migration. Next, we defined different levels of corridor use based on the proportion of the collared migrants in the population for a given grid cell. For most herds, we then defined low use corridors as areas traversed by at least one collared individual during migration, medium use corridors as areas used by 10–20 percent of the collared individuals, and high use corridors as areas used by more than 20 percent of the collared individuals in the population. These corridors were converted from a grid-based format to a polygon format and then isolated-use polygons of less than 4.94 acres (20,000 m^2) were removed. Finally, to calculate stopover use, we averaged all the individual-level UDs to produce a single population-level UD, rescaled to sum to one. Stopovers were defined as the areas representing the highest 10 percent of use from the mean population-level UD. As with the corridors, we then converted stopovers from a grid-based format to a polygon format and removed isolated-use polygons of less than 4.94 acres (20,000 m^2). The resulting population-level corridors are referred to as "corridors" or "footprints," depending on the preference of individual States and Tribes.

Variations of the Method to Calculate Population-Level Corridors

The simplest method for delineating migratory corridors was the line buffer approach (Merkle and others, 2023). For this method, we simply buffered the migration lines (lines connecting sequential GPS locations) by a specified distance (for example, 820 feet [250 meters]) and then used the general methods in the "Calculating Population-Level Corridors and Stopovers" section to determine low, medium, and high use areas. The line buffer method serves as a useful alternative to the BBMM methods because it (1) ensures individual routes are the same width and do not vary extensively, (2) ensures population-level routes have full connectivity between seasonal ranges (in other words, no broken segments or large blobs are produced), (3) easily accommodates variable GPS fix rates, and (4) requires little computing power.

Most maps in this report display low, medium, and high use corridors or routes. However, some individual State and Tribal contributors adapted methods to best suit their management purposes or accommodate the limitations posed by varying sample sizes among herds. The "Data Analysis" section of the page-pair text accompanying each herd provides additional, herd-specific details when analysts deviated from the general methods presented herein, for example, when different definitions were used to define the migration corridor or route use levels.

Estimating a Population's Winter Range

To estimate a population's winter range, we generally followed the same methods used to calculate migration stopover sites but had some exceptions. First, instead of migration sequences, we isolated winter sequences of GPS locations. For each year, we calculated a standard date for the start and end of winter, and based on the preference of individual States and Tribes, we applied one of three options to calculate winter range dates: (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, (2) we defined winter as the dates between the end of fall migration and the start of spring migration for each individual, or (3) we defined a fixed date range using local expert knowledge for a given herd (for example, December 15–March 15). We discarded winter sequences that spanned fewer than 30 days. Following the methods for migration stopovers, we calculated a population-level UD of winter use and identified the core winter range using the 50-percent isopleth. The "Data Analysis" section for the corresponding herd summaries in this report provided additional herd-specific details regarding winter ranges.

Estimating a Population's Annual Range

To estimate a population's annual range, we generally followed the same methods used to calculate migration stopover sites or winter range but had some exceptions. First, we isolated annual movement sequences for each individual. These movement sequences were defined as movements longer than 275 days (200 days for California) in a calendar year, beginning at the time of GPS collar deployment. Start dates were similar because GPS collars were deployed in batches around the same dates. End dates varied depending on individual mortalities. Following the methods for migration corridors, we calculated a population-level UD of annual use and identified the core annual range using isopleth values (for example, 50 and 90 percent contours) selected based on local expert knowledge for a given herd. The "Data Analysis" section for the corresponding herd summaries in this report provided additional herd-specific details regarding annual ranges.

Herd Summary Statistics

In addition to the map for each herd, a number of summary statistics described the project and associated data. In the "Animal Capture and Data Collection" section for the corresponding herd summaries in this report, sample size was defined as the number of collared individuals, inclusive of residents and migrants, relocation frequency was determined by local researchers and varied in and among herds, and the project duration was defined using the year of the first and last GPS location included in the analyses. In the "Data Analysis" section for the corresponding herd summaries in this report, we provided the number of migration sequences and individuals used in the respective analysis. These numbers accounted for sequences that failed to fit a BBMM and were not included in the delineation of the migration corridor or seasonal range. In the "Corridor and Stopover Summary" section for the corresponding herd summaries in this report, we included the median start and end dates for the spring and fall migrations and the average duration of each migration period in days. Additionally, we defined the migration length as the maximum distance between any two points in a spring or fall migration sequence. These methods helped to avoid overestimating migration distances, which can be inflated when calculated as the sum of all step lengths in a sequence because of including distances traveled when foraging at a stopover. The "Corridor and Stopover Summary" section for the corresponding herd summaries in this report also included the areas of migration corridors and stopovers.

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