Elk Habitat Management in Montana W-179-R

Annual interim report, December 2022

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Executive Summary

The Elk Habitat Management in Montana project was initiated to gather information on seasonal habitat use and movements of elk and to evaluate the importance of hunter access management in determining elk distributions during the hunting season. The goals during this reporting period were to 1) collect elk location data in 3 elk populations in central and eastern Montana including the Devil's Kitchen, Custer Forest, and Missouri Breaks populations, 2) begin work on state-wide analysis of factors associated with overabundant elk populations, and 3) begin work on habitat selection analyses in the Devil's Kitchen study area.

We continued to collect location data from collared elk in the Devil's Kitchen area. To augment the sample of male and female elk collared in the Custer Forest area, we instrumented 4 female and 5 male elk in the Custer area on 1/19/2022 via helicopter netgunning. We initiated elk collaring in the Missouri Breaks area north of Jordan, MT. From 1/14/2022 to 1/17/2022, we captured and instrumented 40 adult female and 20 adult male elk in the Missouri Breaks. In both areas, elk were outfitted with Lotek LiteTrack 420 satellite collars programmed to collect hourly location data.

We collected a total of 1,015,857 locations from 65 collared females in the Devil's Kitchen area. We are currently monitoring 43 individuals; 16 mortalities and 6 collar malfunctions have occurred. In the Custer area, we have collected 564,033 locations from 69 collared individuals. We are currently monitoring 47 elk (37 females and 10 males); 9 mortalities and 13 collar malfunctions have occurred. In the Missouri Breaks area, we have collected 248,250 locations from 60 collared individuals. We are currently monitoring 52 elk (38 females and 14 males); 3 mortalities and 5 collar malfunctions have occurred. Movement information collected in all areas has been compiled into preliminary estimates of seasonal ranges and movement corridors and shared on a monthly basis with state and federal agency partners, local landowners, and other members of the public.

We have begun work to evaluate factors associated with overabundant elk populations. The objective of this study is to evaluate factors associated with overabundant elk populations in Regions 2-7 of Montana. We will evaluate the effects of factors such as security habitat, hunter access, and landscape variable on two response variables representing attributes of overabundant elk populations: 1) the proportion over or under objective levels and 2) the population growth rate. For each HD, we will estimate the proportion over or under objective as the current count/ objective number and we will estimate the growth rate using an integrated population model. We have initiated work to estimate the two response variables, as well as development of spatial data.

We have begun work on habitat selection in the Devil's Kitchen area. The objectives of this study are to (1) evaluate the effects of hunting period, harvest regulation, hunter harvest,

migratory behavior, and landscape features on female elk selection of hunter access management strategy during the hunting season, and (2) forecast the consequences of potential changes in harvest regulations on elk distributions and harvest risk. To date, we have developed a database of hunter access management strategies by classifying individual land parcels in the study area into discrete categories (open, controlled, and restricted access) based on personal communication with local land and wildlife managers and private landowners and fit a series of Bayesian multistate models to evaluate the factors influencing the probability that an elk transitioned between hunter access types during the fall hunting season

Project Background

Recently, there has been a focus in the western United States to identify and conserve big game migration corridors and winter ranges, as highlighted in the 2018 Department of Interior Secretarial Order 3362. Seasonal range and movement information is lacking for many elk populations in Montana, particularly in the central and eastern portion of the State. As part of a Montana Fish, Wildlife and Parks (MFWP) initiative to identify elk migration corridors and winter ranges and work cooperatively with partners to conserve these important habitats, there is a need to collect and assess elk movement data. The purpose of this project is to identify seasonal ranges and movement corridors for the Devil’s Kitchen, Custer, and Missouri Breaks elk populations in central and eastern Montana (Figure 1), evaluate the effects of hunter access management and other landscape features on habitat selection in these populations, and provide information to enhance elk management in prairie regions.

Our first goal is to delineate migration corridors and seasonal ranges of 3 elk populations in central and eastern Montana including the Devil’s Kitchen, Custer Forest, and Missouri Breaks populations. These areas have been selected based on the local needs identified by MFWP management biologists, and where considerable community, conservation partner, and agency interest in elk habitat conservation exists. A standardized and comprehensive assessment of movement data will ensure seasonal ranges and movement corridors are appropriately quantified, facilitate comparisons among populations, and result in a comprehensive communication tool that FWP can use to inform local stakeholders and agency partners as they consider ways to improve elk habitat in land use and planning decisions.

This component of the project involves collecting elk location data from GPS-collared elk in the 3 study areas for 3 years (Figure 1). We have developed methodologies for delineating seasonal ranges and corridors in collaboration with the USGS corridor mapping team and scientists in other state agencies utilizing Brownian bridge and kernel-based movement models. We will estimate seasonal core use areas during winter (Dec 15 – March 1), calving/fawning (May 25-June 10), summer (July 1 – August 31), and hunting seasons (approx. Sept 1 – Nov 30), and summarize the attributes of seasonal ranges. We will identify important movement corridors by estimating population-level migration routes (e.g., Horne et al. 2007, Kranstauber et al. 2012, Thurfjell et al. 2014, Avgar et al. 2016). Movement-based models are useful for mapping population-level movement corridors and identifying corridors with the highest levels of use. Summaries and maps of location and movement data will be presented in documents designed for landowners and managers that are intended for use in local decision making.

We anticipate that fine-scale location data collected in the Devil's Kitchen study area will help to identify important seasonal habitats and movement corridors and provide information regarding the timing of movements. This information may then be used to refine harvest management strategies that maximize the effectiveness of elk management in the area. Landowners, MFWP, and community members are presently engaged in a longstanding community working group (Devil's Kitchen Working Group) that regularly meets to discuss elk management in the area. The results of this study will aid these conversations on elk management and facilitate stronger conservation-oriented discussions. We anticipate that fine-scale location data collected in the Custer Forest and Missouri Breaks will also provide new information to inform management aimed at achieving more desirable elk distributions and harvest.

Our second goal is to broadly evaluate factors such as habitat quality, security, and hunter access to investigate and compare attributes of problematic and non-problematic elk distributions. We define problematic elk distributions as elk distributions during the fall and winter hunting seasons that result in failure to achieve female harvest objectives. While it is generally understood that existing problematic elk distributions may be driven by harvest regulations, restrictive hunter access management, landscape factors, or a combination of these factors, a formal assessment is necessary to assess whether elk herds that are or are not characterized by problematic distributions differ among these drivers. This will involve summary analyses of existing data from populations across the state.

To address our second goal, we will combine and analyze existing elk GPS collar data at a statewide scale to broadly evaluate factors associated with problematic elk distributions. Currently, the degree to which elk populations are over objective is hypothesized to relate to the amount of land with restrictive hunter access; however, this hypothesis has not been broadly evaluated, and other landscape attributes may also influence problematic distributions. We plan to utilize a resource selection modeling approach to evaluate how the strength of elk selection for private lands with restricted hunter access varies across populations. We plan to relate the amount of land with restrictive access and selection coefficients to the degree elk populations exceed objective levels to test the hypotheses that hunter access management and/or elk selection behaviors are associated with the degree to which populations are over objective.

Our third goal is to evaluate the effects of hunter access management and other important factors on elk habitat selection in the Devils Kitchen, Custer Forest, and Missouri Breaks areas, particularly during the fall hunting seasons. We will use location data collected from GPS collared elk in the Devils Kitchen, Custer Forest and Missouri Breaks study areas to evaluate elk habitat selection. Lands with restrictive hunter access may serve as refuges, and elk may aggregate in these areas to escape harvest risk during the hunting seasons (Conner et al. 2001, Vieira et al. 2003, Proffitt et al. 2013). If factors such as security, forage and hunter access can be identified and related to habitat selection, managers may use this information to design management plans to manipulate these factors and increase the amount of time elk spend on public land. This could facilitate further opportunity for hunters using public lands and reduce game damage incurred on adjacent private lands. By increasing our understanding of these central Montana and prairie elk populations, FWP will be better able to sustainably provide harvest opportunity, minimize game damage and problematic distributions, and work with private and public land stewards to manage habitat that benefits elk.

MFWP and partners have invested considerable resources in evaluating the effect of factors such as hunter access management and elk security on elk distributions in the mountains and forested landscape of western Montana (Ranglack et al. 2017, DeVoe et al. 2019, Lowrey et al. 2020). However, no such studies have been conducted in central Montana and only 1 study has evaluated factors affecting elk distributions during the hunting season in prairie environments (Proffitt et al. 2016). This lack of information creates a challenge for wildlife managers in central Montana and the prairie regions. To address our third goal, we will build from previous security habitat studies in Montana and provide information and recommendations as to population and habitat management strategies for elk in central Montana and the prairie environments of eastern Montana following a similar approach (Proffitt et al. 2013, 2016, DeVoe et al. 2019, Lowrey et al. 2020).

Information gained from this project will be used for on-the-ground implementation by FWP and partners to manage, protect, and improve important elk habitats and develop strategies to manage elk populations at desired abundances and distributions. Implementation may include working with public and private landowners to improve security and/or habitat quality, remove barriers impeding movement, or may include recommendations for hunter access management.

We continued work on our first goal and began work on goals 2 and 3 during this reporting period. Our objectives during this reporting period were:

1. Capture and collar elk in the Custer area to augment a sample of collared elk captured in 2022 and capture, collar, and sample up to 60 elk (20 males, 40 females) in the Missouri Breaks study area.
2. Collect and archive elk location data in the Devil's Kitchen, Custer, and Missouri Breaks study areas.
3. Begin work on state-wide analysis of factors associated with overabundant elk populations.
4. Begin work on habitat selection analyses in the Devil's Kitchen study area.

Location

This research is being conducted in portions of Cascade, Lewis and Clark, Garfield, Powder River, Bighorn, and Rosebud River Counties (Figure 1). The Devil's Kitchen elk population occupies Lewis and Clark and Cascade Counties and spans portions of hunting districts (HD) 445, 455 and 446. There are approximately 4,000 elk distributed across several winter ranges.

The Custer elk population occupies Powder River, Bighorn, and Rosebud Counties and spans portions of HD 704 and 705. This elk population has grown to approximately 1,700 elk since surveys began in 2005. The annual range includes a mixture of privately-owned ranchlands, sagebrush and mixed-grass prairies, and xeric, ponderosa pine (*Pinus ponderosa)* dominated forest communities.

The eastern Missouri Breaks population (hereafter Missouri Breaks) occupies Garfield County and is within HD 700. In the last 3 surveys conducted during the last six years, the population count ranged from 800 to 1,500 elk. During the most recent survey conducted in winter 2020, a total of 1,300 elk were counted. Survey data suggests the elk population is 500-1200 individuals above the population objective of 200-300 individuals. The annual range includes a mixture of privately-owned ranchlands and sagebrush, mixed-grass prairies, and ponderosa pine forest communities.

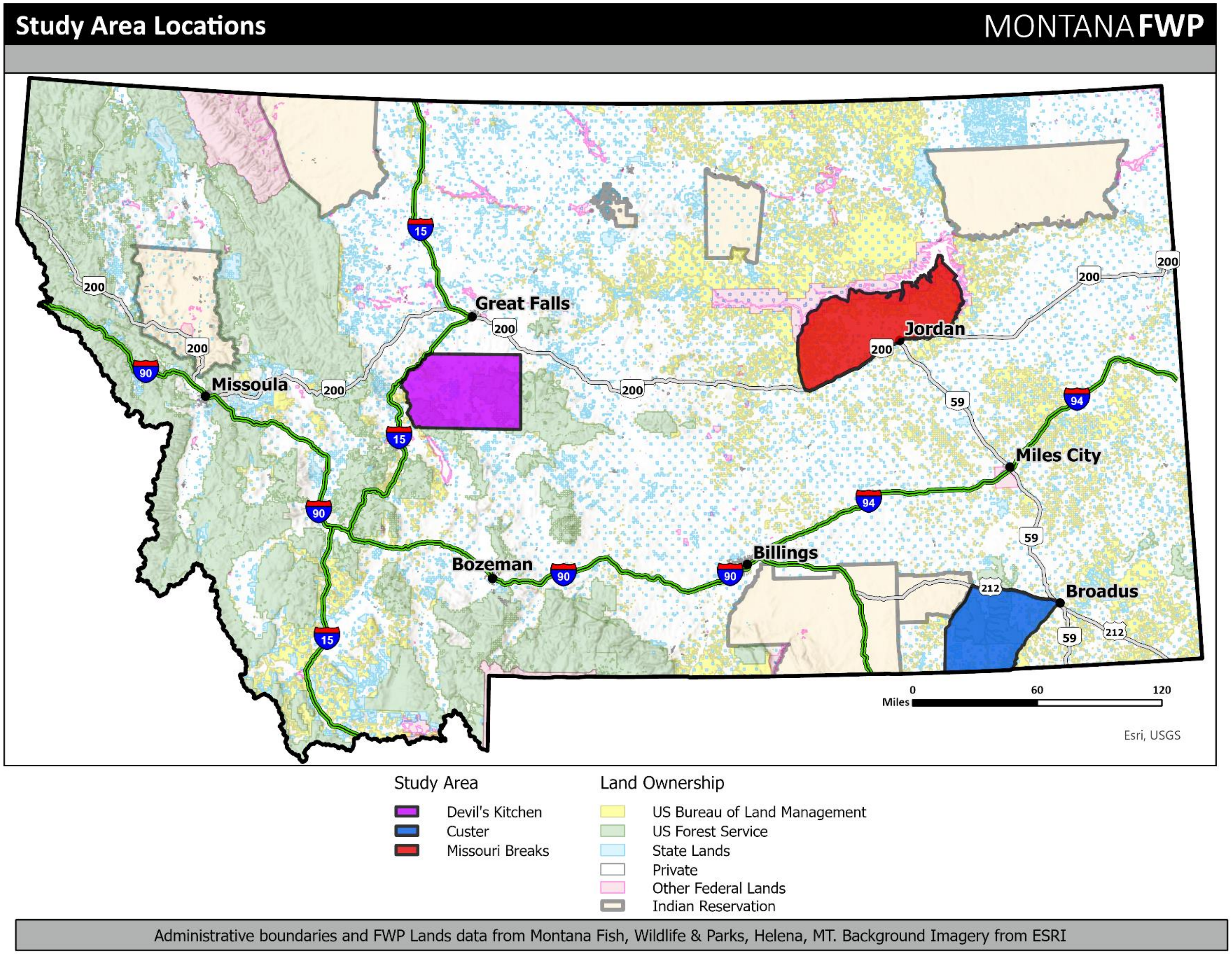


Figure 1. The Devil's Kitchen, Custer Forest, and Missouri Breaks study areas in central and eastern Montana.

Objective 1: Capture and collar elk in the Custer area and capture, collar and sample up to 60 elk (20 males, 40 females) in the Missouri Breaks study area.

1.1 2022 Custer elk capture and collaring

We used helicopter net-gunning to capture and collar a total of **9** elk (4 female, 5 male) in the Custer study area on January 19, 2022 (Figure 2) to augment a sample of previously collared animals in the study area. A detailed explanation of previous capture operations for this study area can be found in earlier versions of this annual report. A total of 69 animals have been collared in the Custer study area to date. We outfitted captured individuals with Lotek LiteTrack Iridium collars programmed to collect hourly locations for 2 years. The collars were programmed to transmit a VHF signal during daylight hours and switch to a mortality signal if stationary for >10 hours. Collars upload locations via Iridium satellites to a web platform where data can be viewed and downloaded in near-real-time. We obtained blood serum samples from 4 collared females and submitted these for pregnancy testing; all 4 females were classified as pregnant.

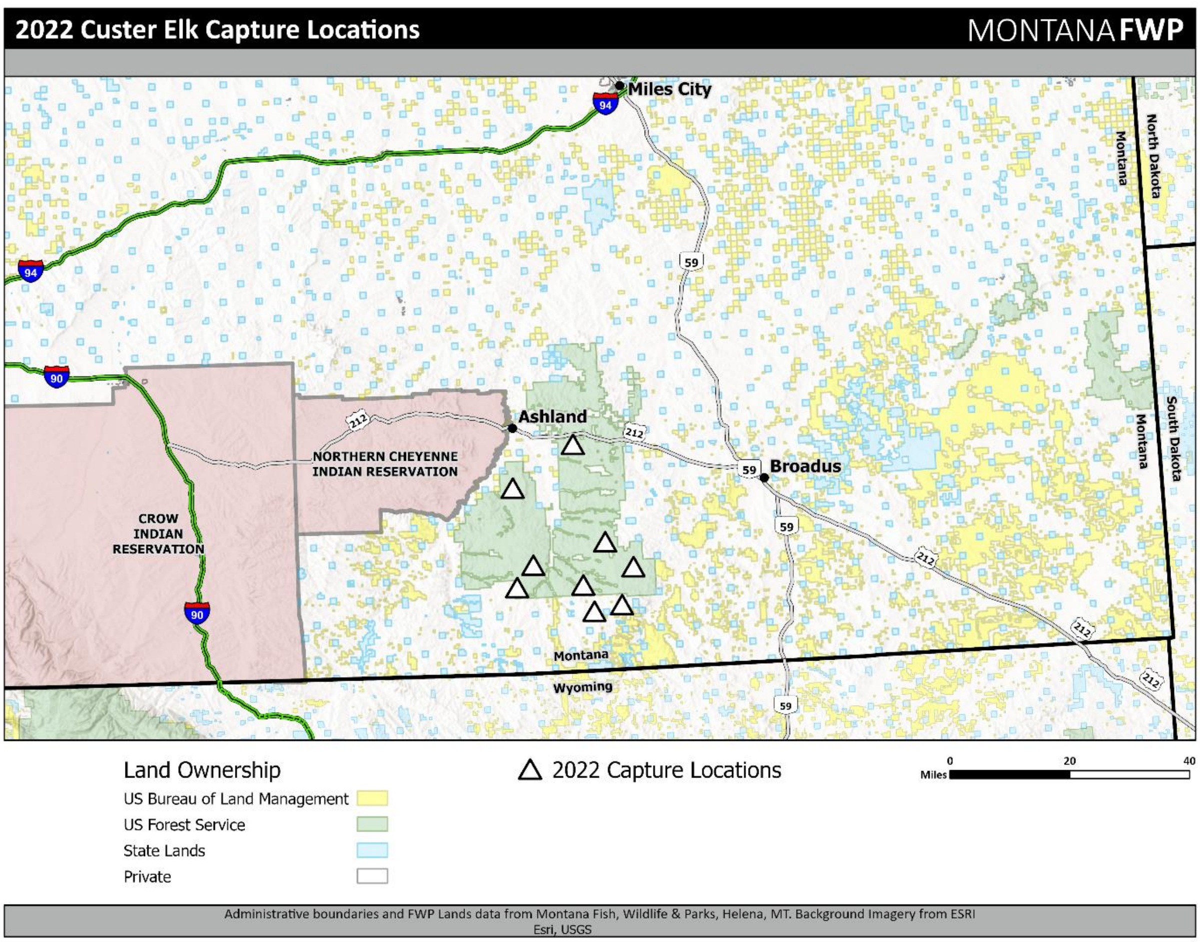


Figure 2. Capture locations for the 9 elk captured and collared in the Custer study area in 2022. Captures took place on the Custer National Forest and surrounding BLM, state, and private lands south of Highway 212 and west of Broadus, MT.

1.2.1 2022 Missouri Breaks elk capture, sampling, and collaring

We used a combination of aerial darting and helicopter net-gunning to capture and collar a total of 40 female and 20 male elk in the Missouri Breaks study area from 1/14/2022 to 1/17/2022 (Figure 5). We outfitted captured individuals with Lotek LiteTrack Iridium collars programmed to collect hourly locations for 3 years. The collars were programmed to transmit a VHF signal during daylight hours and switch to a mortality signal if stationary for >10 hours. Collars upload locations via Iridium satellites to a web platform where data can be viewed and downloaded in near-real-time. During captures, we obtained blood serum samples from 40 captured females and submitted these samples for a full serology screening and pregnancy testing. For each female, we also pulled a tooth for aging purposes via cementum annuli, estimated a body condition score, obtained a fecal pellet sample for dietary analysis, and obtained a measurement of rump fat thickness. Females were on average 6.0 years old (SD = 2.79, range = 2.5 to 13.5 years old). We are awaiting dietary analysis results but provide an overview of pregnancy, serology, and body condition results below.

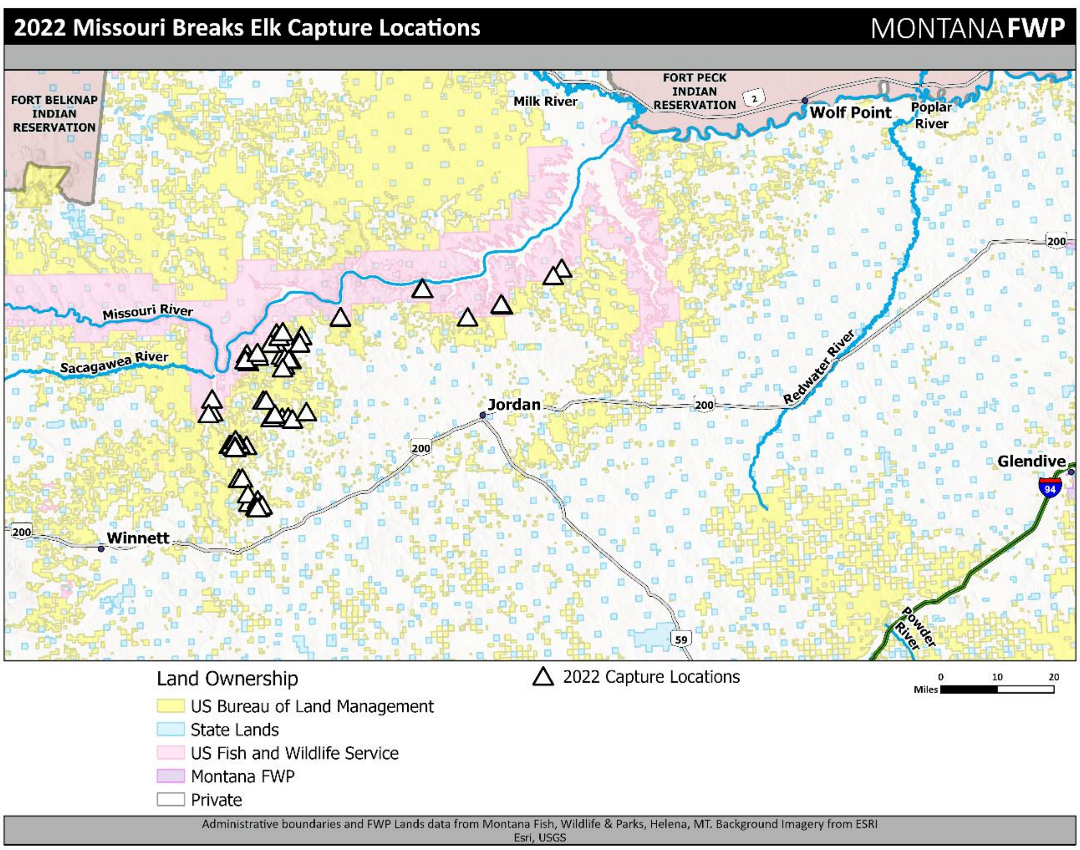


Figure 3. Capture locations for the 60 (40 female, 20 male) elk captured and collared in the Missouri Breaks study area in 2022. Captures took place on the Charles M. Russell National Wildlife Refuge, BLM, and surrounding BLM, state, and private lands north and east of Jordan, MT.

1.2.2 Missouri Breaks Sampling Results

1.2.2.1 Pregnancy

We sent blood serum samples from 40 captured females to be tested for PSPB (Herd Health Diagnostics/BioTracking Testing Lab, Pullman, Washington). PSPB values were classified into categories that are typical for wildlife species: open (values ≤ 0.210) and pregnant (values > 0.210). PSPB levels (measured as an optical density) in the Missouri Breaks study area averaged 0.6240 (SD = 0.278; range = 0.056 to 0.790). Of the 40 females whose blood serum was sent for PSPB testing, 32 were classified as pregnant. The percentage of pregnant adults in the Missouri Breaks study area (80%), was below the state-wide average (87%).

1.2.2.2 Serology

Blood serum samples from 40 adult female elk were assayed for evidence of exposure to pathogens including *Brucella abortus*, Anaplasma bacteria, Leptospirosis, parainfluenza-3 (PI-3), bovine respiratory syncytial virus (BRSV), bovine viral diarrhea type 1, bovine viral diarrhea type 2 (BVD I and II), bovine herpesvirus- 1 (BHV-1), and epizootic hemorrhagic disease. These pathogens were selected for screening because of their potential to influence individual or herd health in wildlife and/or livestock. All assays were conducted by the Montana Veterinary Diagnostic Laboratory (MVDL; Bozeman, Montana).

Evidence for exposure varied by pathogen (Table 1). We found no serological evidence of exposure to *B. abortus*, leptospirosis, BRSV, BVD 1, or BVD 2. We did find evidence of exposure to Anaplasma (52% seroprevalence), PI-3 (68% seroprevalence), BHV-1 (12% seroprevalence), and EHD (62% seroprevalence). A brief description of each detected pathogen and its influence (if known) on individual and herd health can be found below.

Statistic	BRUC	ANAPL	LEPTO	PI3	BRSV	BVD 1	BVD 2	BHV-1	EHD
# Sampled	40	40	40	40	40	40	40	40	40
# Exposed	0	21	0	27	0	0	0	5	25
% Exposed	0	52	0	68	0	0	0	12	62

Table 1: Seroprevalence of brucellosis (BRUC), anaplasmosis (ANAPL), leptospirosis (LEPTO), paraininfluenza-3 (PI3), bovine respiratory syncytial virus (BRSV), bovine viral diarrhea type 1 (BVD 1), bovine viral diarrhea type 2 (BVD 2), bovine herpesvirus-1 (BHV-1), and epizootic hemorrhagic disease (EHD) based on serological screening of adult female elk in the Missouri Breaks during the winter of 2022.

Anaplasmosis
Anaplasmosis, a sickness caused by bacteria of the genus *Anaplasmaisa*, is a vector-borne disease primarily affecting domestic cattle. *Anaplasma marginale*, the species most involved with infections in cattle, affects red blood cells resulting in severe anemia and sometimes death. Elk are susceptible to Anaplasma infection. However, serious clinical signs have not been recorded and there is little evidence suggesting elk are important carriers or reservoirs of the disease (Kuttler 1984; Zaugg et al. 1996). The specific Anaplasma species the elk were exposed to in the Missouri Breaks are unknown because the test detects antibodies for multiple species. This pathogen is not expected to impact individual or herd health in elk.

Parainfluenza-3
Parainfluenza-3 is a common virus that can be involved in respiratory disease in domestic ungulates. The disease associated with PI-3 is usually mild or subclinical, but under severe stress, the virus may predispose animals to coinfection with other respiratory pathogens resulting in development of secondary bacterial pneumonia. It is unknown whether exposure to this virus leads to clinical symptoms in free-ranging elk (Barber-Meyer et al. 2007). Evidence of exposure on serological testing is common in wildlife but documented clinical cases of disease are not. Exposure to this virus is not expected to impact individual or herd health.

Bovine viral diarrhea (types 1 & 2)
Bovine viral diarrhea virus (types 1 & 2) can cause bloody diarrhea and can induce immunosuppression resulting in development of secondary bacterial pneumonia in domestic and wild ungulates. The different types (1 & 2) reflect differences in the antigens found on the viral surface protein and do not relate to the virulence of the virus. Elk are susceptible to infection with BVD, but there is little evidence of serious clinical effects (Tessaro et al. 1999). There is potential for wildlife populations to serve as reservoirs of this virus (Duncan et al. 2008).

Epizootic hemorrhagic disease
Epizootic hemorrhagic disease (EHD) is caused by a virus that is transmitted by biting midges in the *Culicoides* genus and other arthropods. EHD can cause acute and frequently fatal hemorrhagic disease in domestic and wild ungulates. Recurrent outbreaks of EHD-associated mortality occur in white-tailed deer and mule deer, primarily in eastern Montana (Montana Fish, Wildlife and Parks Wildlife Health Lab, unpublished data). Elk are susceptible to epizootic hemorrhagic disease, but generally do not suffer high rates of mortality or show clinical symptoms (Hoff 1973; Nol et al. 2010). Epizootic hemorrhagic disease virus exposure was detected in 62% of sampled female elk in the Ashland study area. There is some concern that elk could act as reservoirs of EHD, allowing the vectors (biting midges) to transmit the virus to other wildlife during the right environmental conditions (Thorne et al. 2002), but such relationships are not well studied.

1.2.2.3 Body Condition

We estimated a body condition score and maxfat value for 36 females in the Missouri Breaks. Body condition scores can range from 1 (very poor) to 5 (very high). We also measured the maximum rump fat thickness in centimeters (maxfat) using a portable ultrasound. The average body condition score was 3.84 (range: 3.25 - 4.25), higher than the state-wide average of 3.54. Maxfat measurements averaged 0.48 cm (range: 0.00 - 1.00), coming in below the state-wide average of 0.74. The average percent ingesta-free body fat (IFBF) value for captured females in the Missouri Breaks was 8.18%, which is higher than the state-wide average of 7.80% (Figure 4).

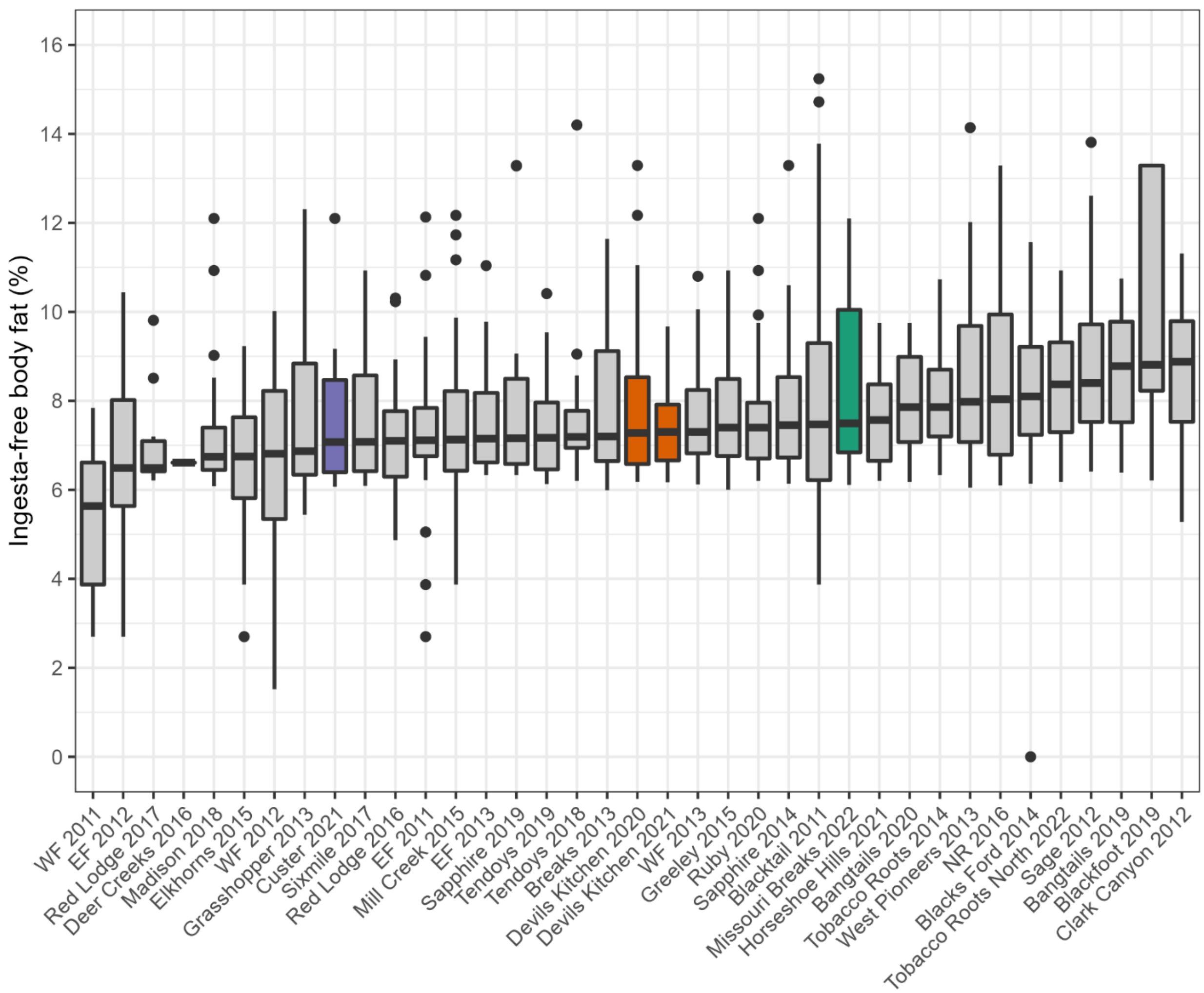


Figure 4. Estimated ingesta-free body fat percentage (IFBF) for the Missouri Breaks study area (green) relative to IFBF estimates from the Custer study area (purple), Devil's Kitchen study area (orange), and herds across the state (grey). The upper and lower bounds of the boxes (hinge) represent the 25th and 75th percentiles. The whiskers extending from the hinge represent the maximum and minimum values respectively that are no more than 1.5 times the interquartile range from the hinge. Data occurring beyond the end of the whiskers are outlying points and are plotted individually.

Objective 2: Collect elk location data in all 3 study areas

2.1 Devil's Kitchen Location and Movement Data Collection

As of September 30, 2022, we have gathered 1,015,857 locations from 65 individuals in the Devil's Kitchen study area for an average of 15,629 (range = 214-22,003) locations per individual. A detailed explanation of capture operations for this study area can be found in previous versions of this annual report. We have recovered collars from 16 mortalities in the area; 5 were legally harvested during the 2020 hunting season, 6 were harvested during the 2021 hunting season, 3 died due to natural causes, and 2 were classified as capture-related mortalities. An additional 6 collars have malfunctioned for unknown reasons. We are currently monitoring 43 female elk in the area. Monthly reports have been generated and distributed to regional MFWP staff as well as other agency partners, private landowners, and other members of the public.

Preliminary estimates of seasonal ranges (Figures 5 and 6) and movement corridors (Figure 7) were compiled after a full year of data collection and will be finalized when data collection is complete. This information was synthesized from GPS location data using the Migration Mapper application (Merkle et al. 2022) to visually classify migratory behaviors and movement periods using maps of GPS locations and associated net-squared displacement (NSD) curves for each individual. Population-level movement corridors were outlined using two variations of the Brownian bridge movement model (Horne et al. 2007). We used kernel density estimates (KDE) to delineate seasonal range distributions. Corridors and home ranges were constructed using locations gathered in the Devil's Kitchen area through May 2022.

Movement data from the Devil's Kitchen area (Figure 8) reinforces local reports of a seasonally occurring migratory behavior exhibited by a portion of this population. This movement takes place between the Beartooth Wildlife Management Area (BWMA) and private ranchlands in the valley bottom, with movements onto the BWMA occurring most often in the late fall and early winter months. Seasonal migratory movements occur in other portions of the study area as well. We have also observed movement patterns that appear typical of resident animals dispersed throughout the study area. Individual elk land use in the Devil's Kitchen area shows high proportional use of private lands across all seasons with an increase in proportional use of the BWMA in the fall and winter (Figure 9).

2.1.1 Preliminary Devil's Kitchen Elk Seasonal Ranges and Movement Corridors

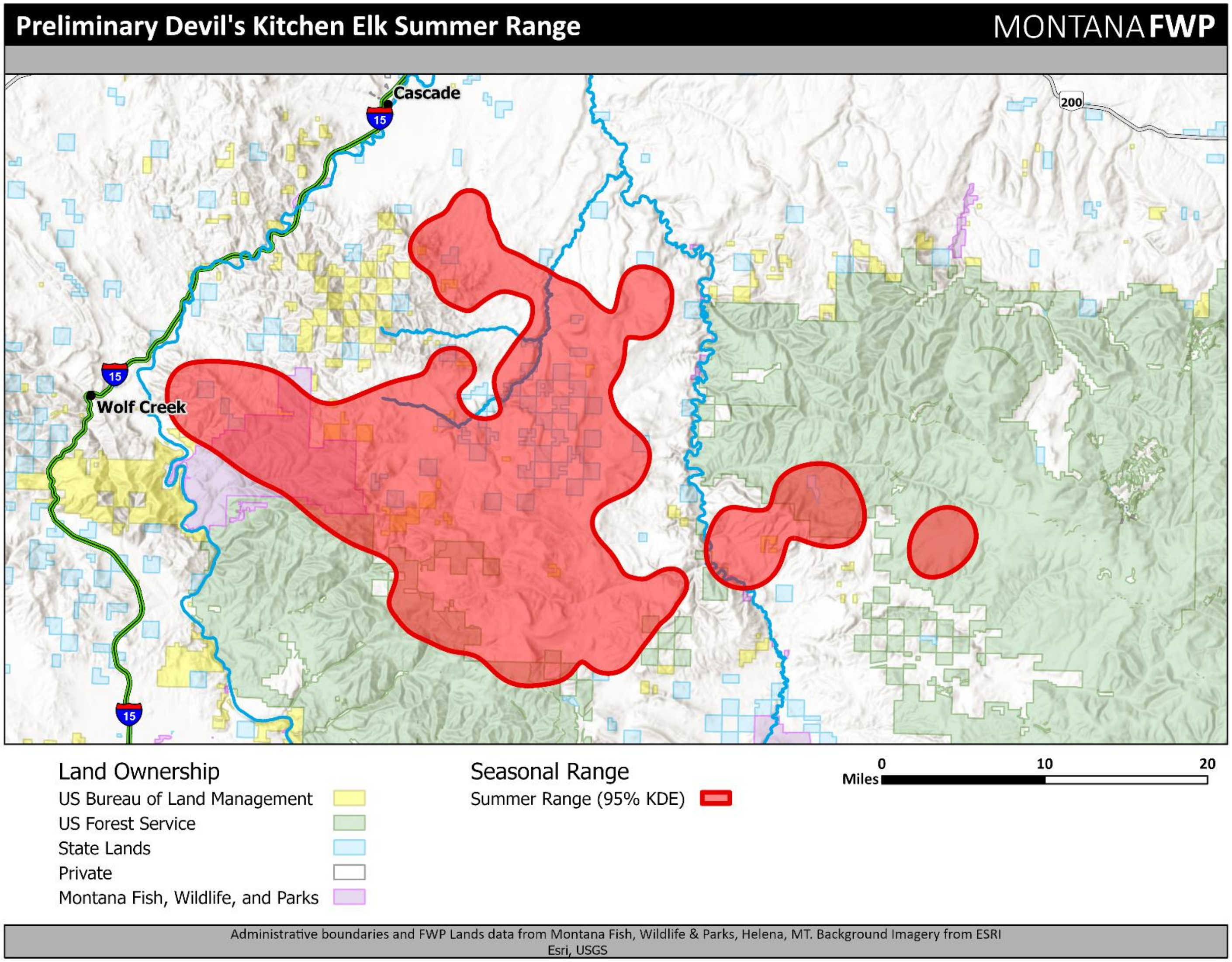


Figure 5. Estimated summer range for elk collared in the Devil's Kitchen area based on locations gathered through May 2022. Seasonal ranges were delineated using 95% kernel density estimates (KDE).

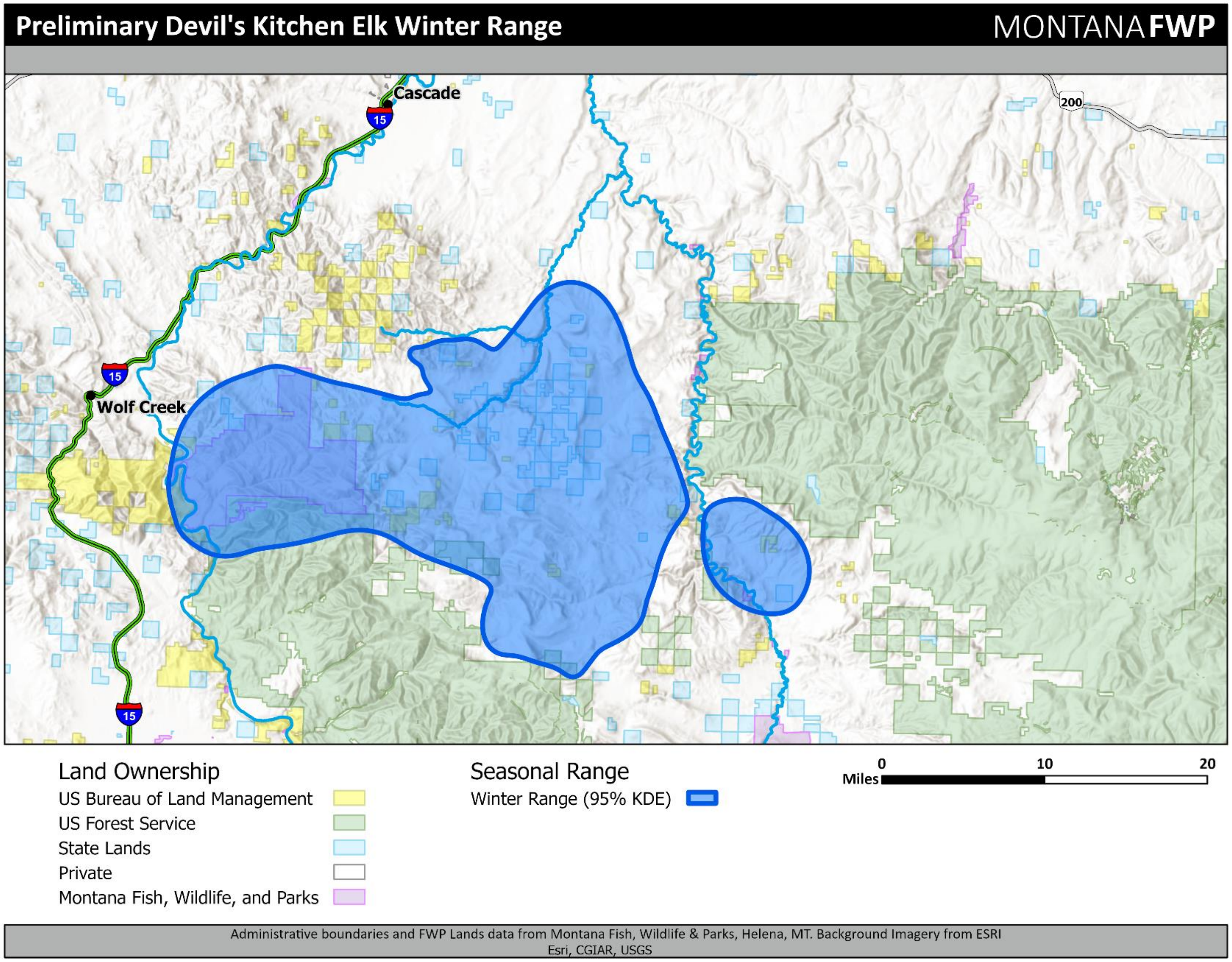


Figure 6. Estimated winter range for elk collared in the Devil's Kitchen area based on locations gathered through May 2022. Seasonal ranges were delineated using 95% kernel density estimates (KDE).

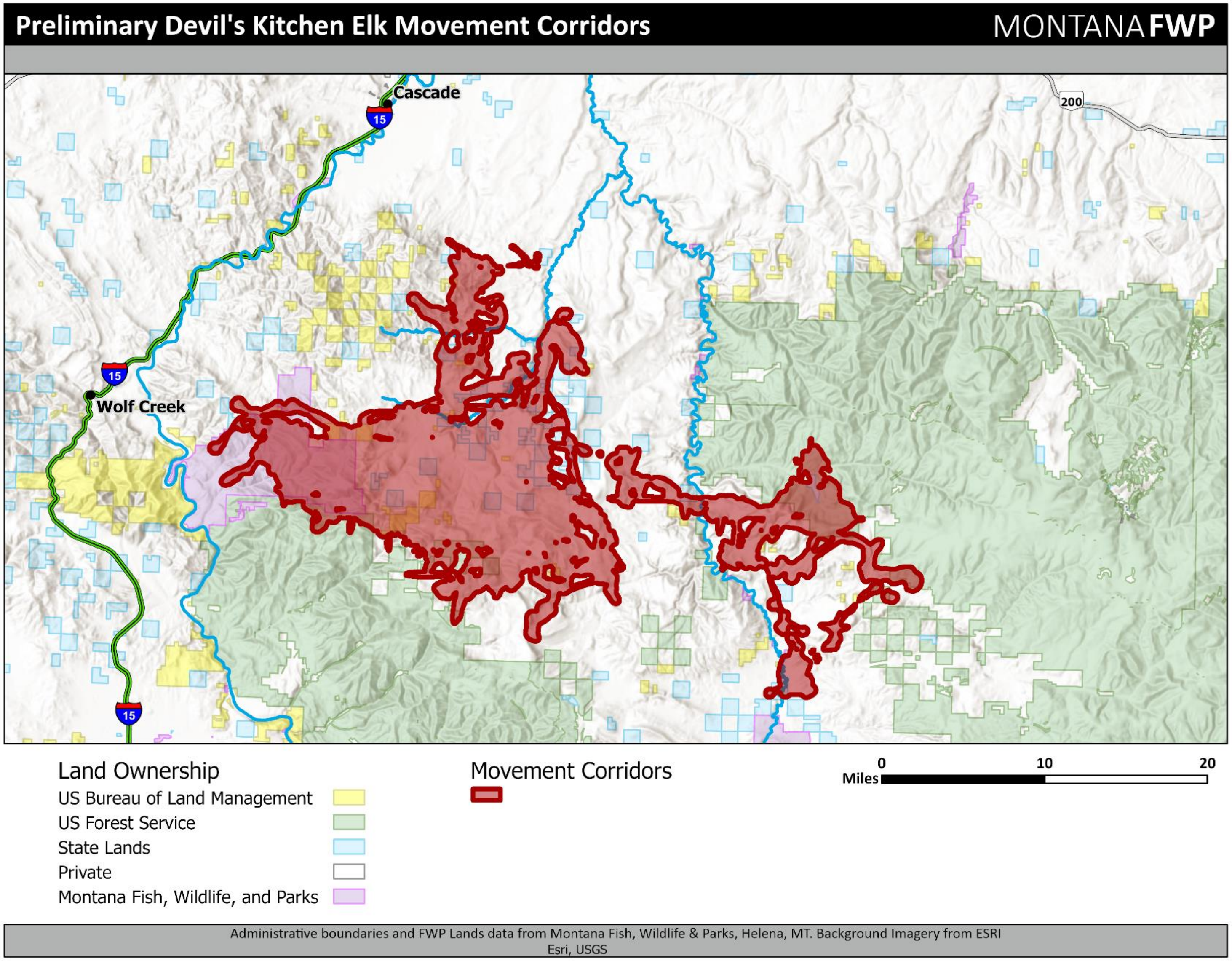


Figure 7. Movement corridors delineated for elk collared in the Devil's Kitchen area based on locations gathered through May 2022. Corridors were constructed using the Migration Mapper application and Brownian bridge movement models.

2.1.2 Devil's Kitchen Elk Locations and Movements

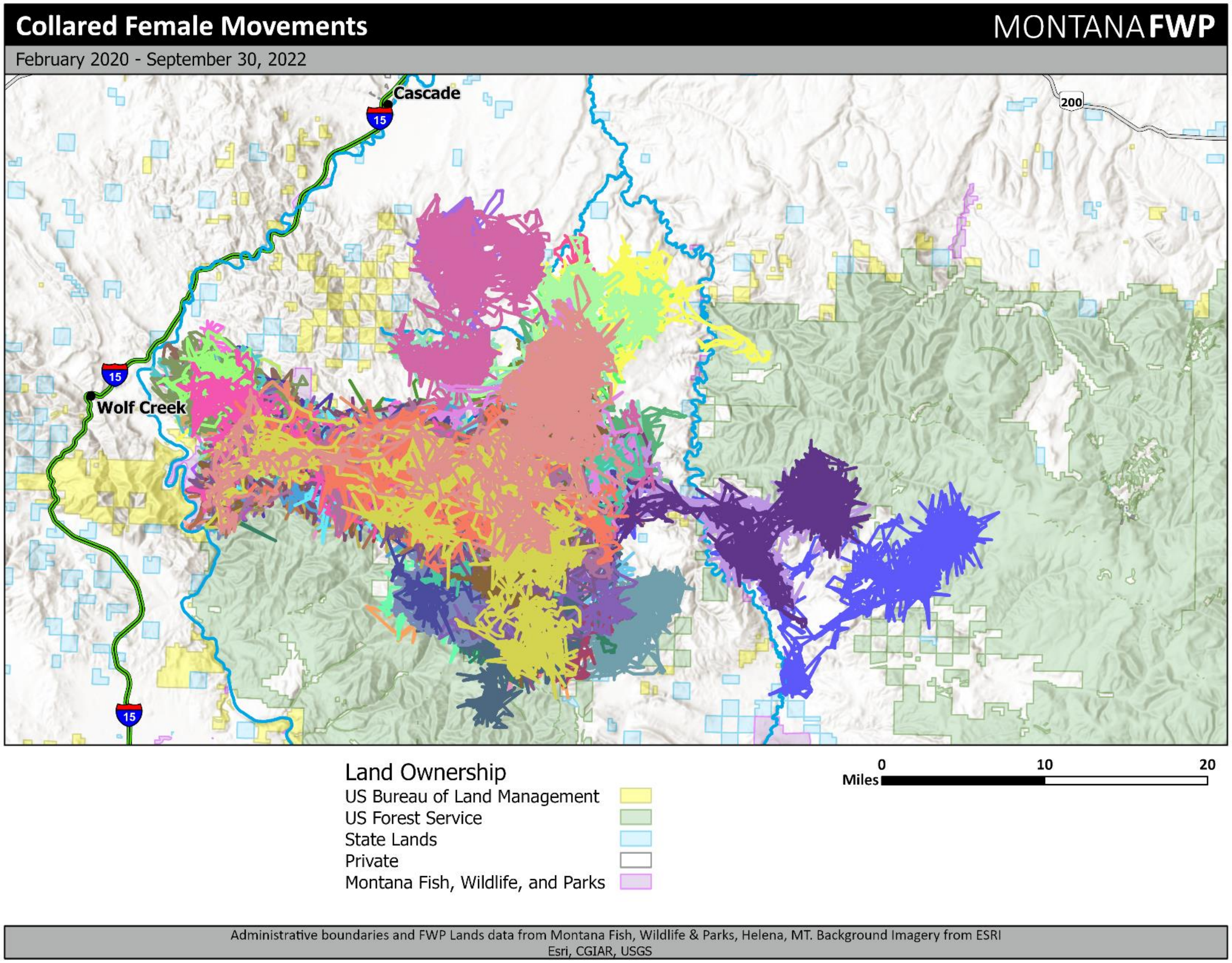


Figure 8. Movements of 65 collared individuals in the Devil's Kitchen study area through September 30, 2022.

2.1.3 Devil's Kitchen Elk Land Use

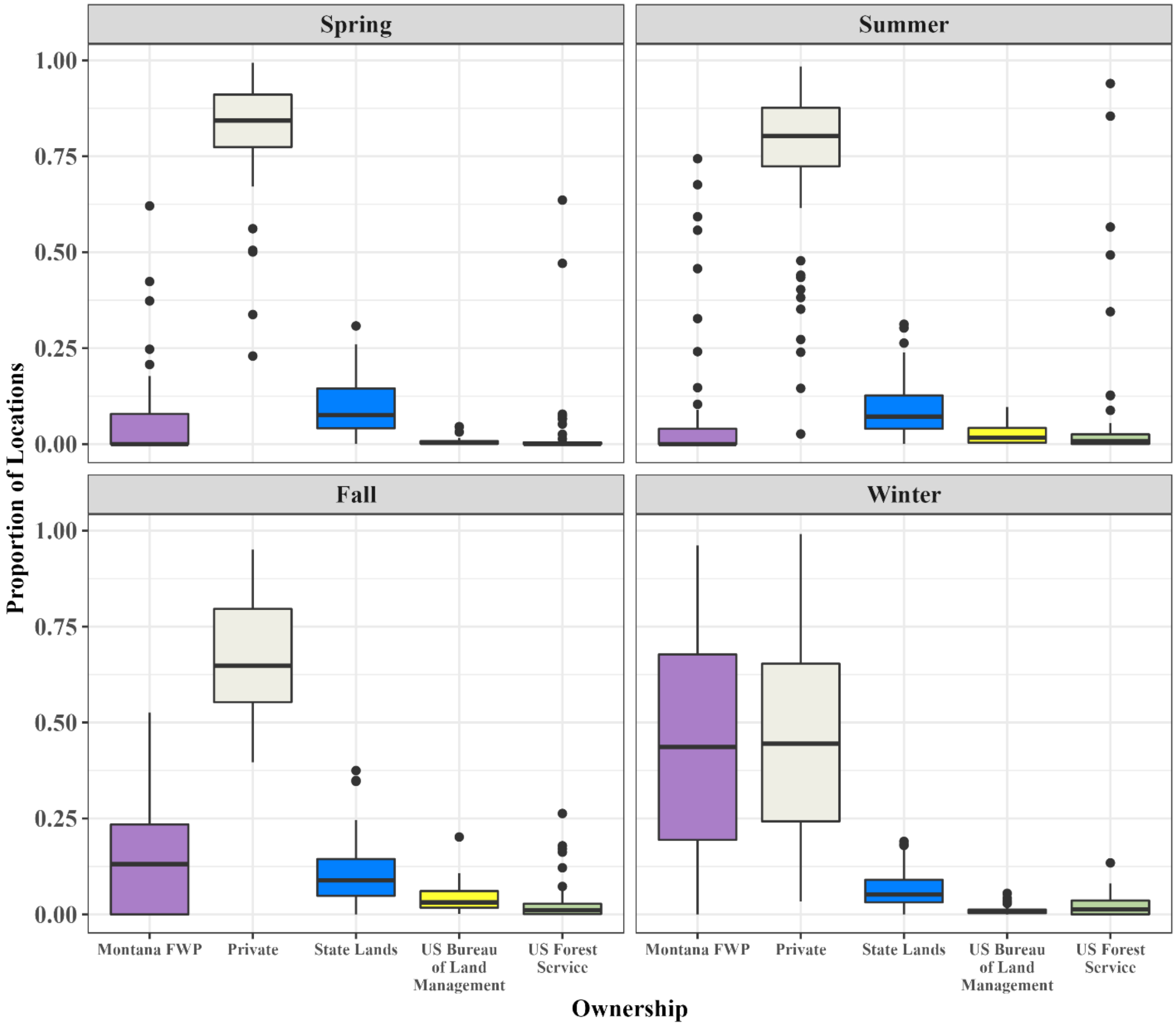


Figure 9. Proportional use of state, federal, and private lands by individual elk and season in the Devil's Kitchen study area. With the exception of some BLM lands that are accessible via helicopter, Montana State Trust and BLM lands in this study area are mostly inaccessible to the public.

2.2 Custer Elk Location and Movement Data Collection

As of September 30, 2022, we have gathered 564,033 locations from 69 individuals in the Custer study area for an average of 8,174 (range = 2316-11153) locations per individual. We have recorded 13 collar malfunctions and 9 mortalities. Five elk (3 males, 2 females) were harvested during the 2021 hunting season, 1 elk died due to mountain lion predation, 2 died from unknown causes, and one died from human-related causes. We are currently monitoring 47 individuals (10 males, 37 females). Monthly reports have been generated and distributed to regional MFWP staff as well as other agency partners, private landowners, and other members of the public. . Preliminary estimates of seasonal ranges (Figures 10 and 11) and movement corridors (Figure 12) were compiled after a full year of data collection and will be finalized when data collection is complete. An explanation of the process used to delineate seasonal ranges and movement corridors can be found on page 13.

We have observed a variety of individual movement patterns in both male and female collared elk (Figures 13 and 14). Three males have made forays across the border into Wyoming but returned to Montana shortly thereafter. In August 2022, a collared male moved east to the Ekalaka Hills before continuing on into northwestern South Dakota where it is currently located, tracing a path over 100 miles long. Collared female movements have shown similar diversity, though on average have travelled a larger distance than males since capture. In June 2021, two females moved west onto the Crow Reservation near the I-90 corridor, and 1 individual moved east to loop into North Dakota before returning to the Custer National Forest. We have also observed female movements that looped south into Wyoming before returning to Montana. To date, serious, population-level barriers to animal movements have not been identified in the area. The large movements undertaken by multiple individuals suggest that elk are able to access and connect patches of habitat across a large portion of southeastern Montana. Lands managed by the BLM are an important component of habitat connectivity in this area of the state. We will continue to monitor and evaluate animal movement patterns and will provide this information for use in management decisions.

The location data collected in the Custer area thus far indicates that elk primarily use privately owned lands (50% of locations) and the Custer National Forest (40% of locations); 6% of locations gathered so far have occurred on lands managed by the BLM. Some collared individuals use BLM lands at much higher rates; a maximum of 51% of an individual's locations have occurred on BLM managed lands thus far. Land managed by the BLM in the southern portion of the study area between the state line and the edge of the Custer National Forest is frequently used by collared elk. Patterns of the distribution of locations across land ownerships are similar across seasons (Figure 15).

2.2.1 Preliminary Custer Elk Movement Corridors and Seasonal Ranges

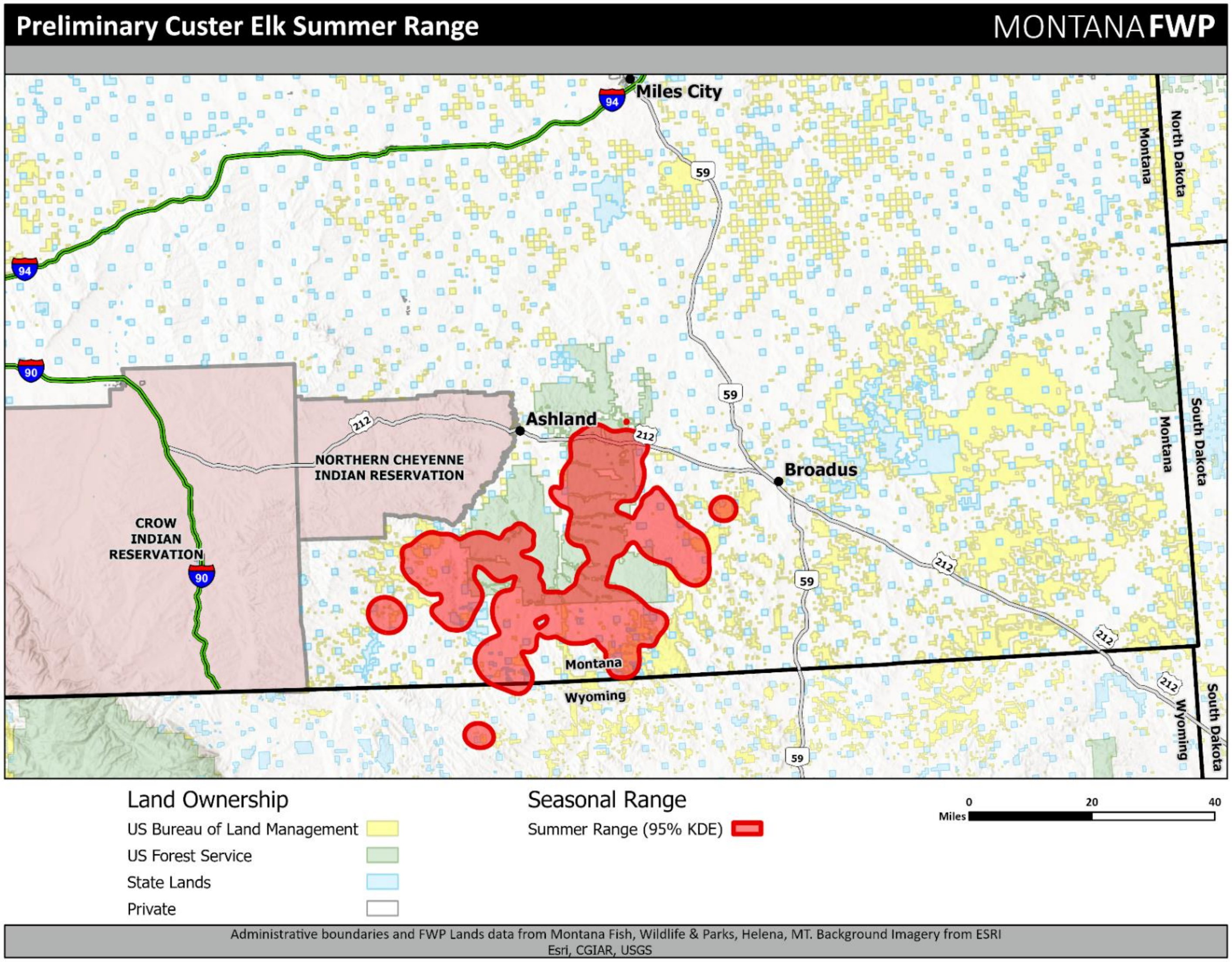


Figure 10. Estimated summer range for elk collared in the Custer area based on locations gathered through May 2022. Seasonal ranges were delineated using 95% kernel density estimates (KDE).

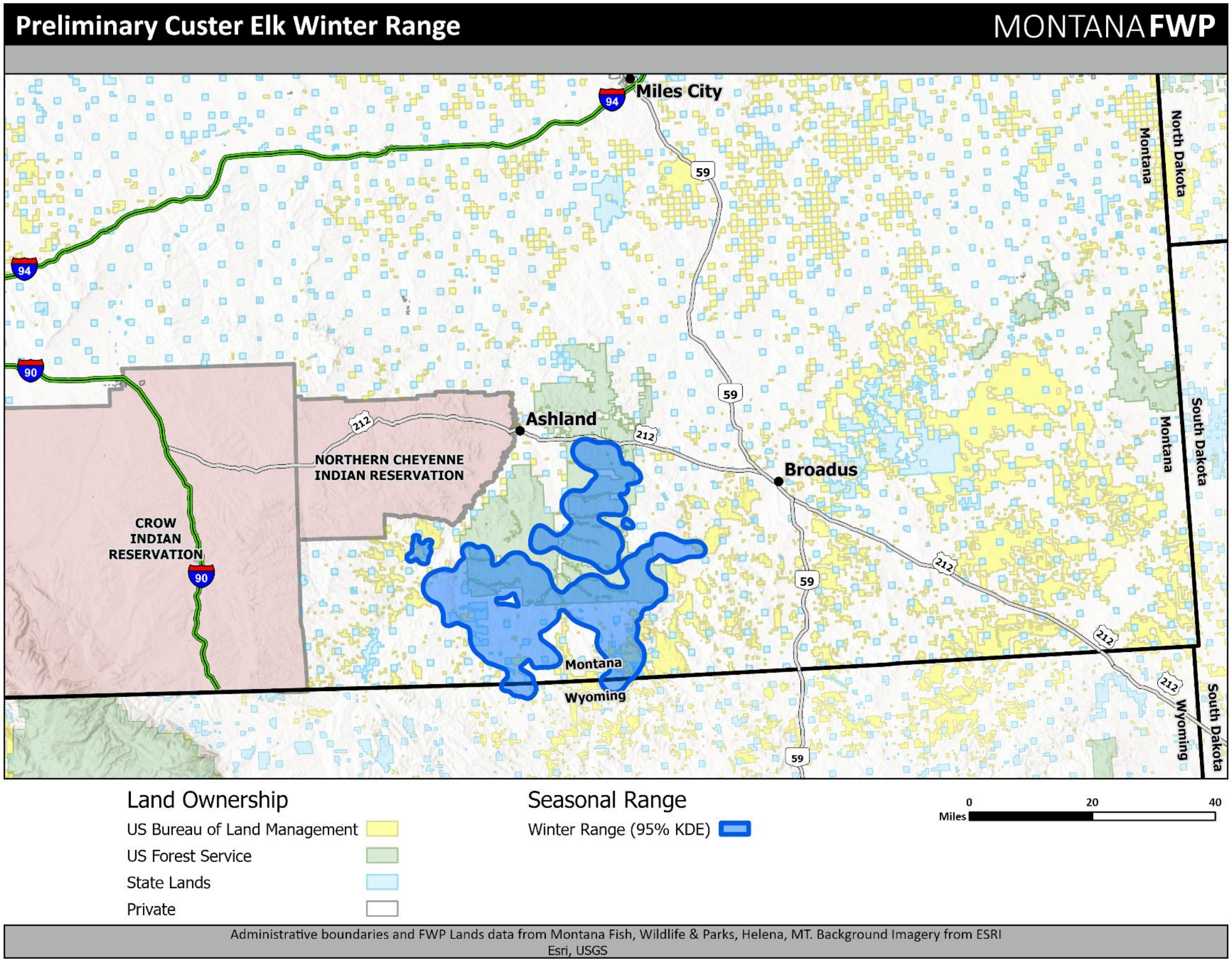


Figure 11. Estimated winter range for elk collared in the Custer area based on locations gathered through May 2022. Seasonal ranges were delineated using 95% kernel density estimates (KDE).

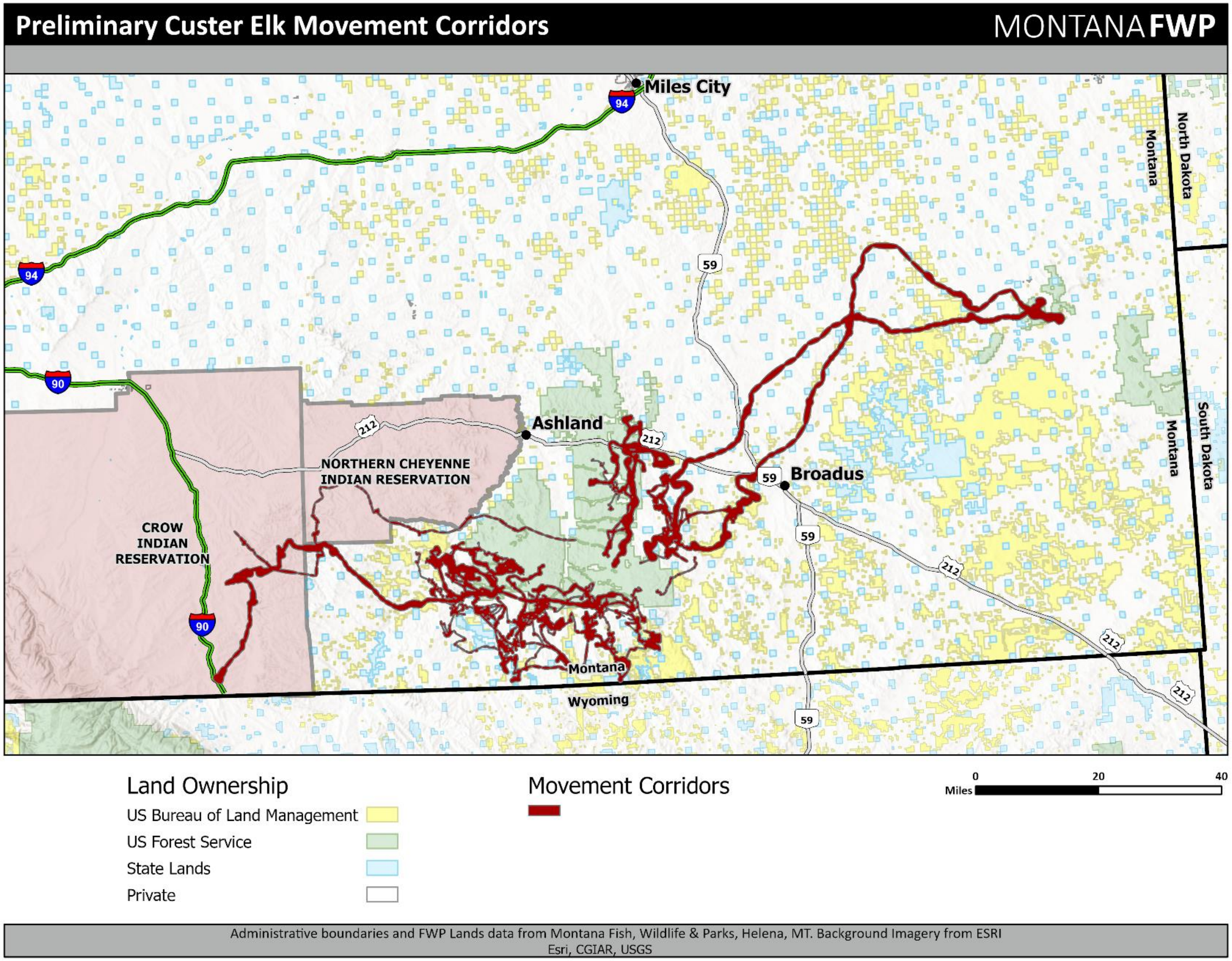


Figure 12. Movement corridors delineated for elk collared in the Custer area based on locations gathered through May 2022. Corridors were constructed using the Migration Mapper application and Brownian bridge movement models.

2.2.2 Custer Elk Locations and Movements

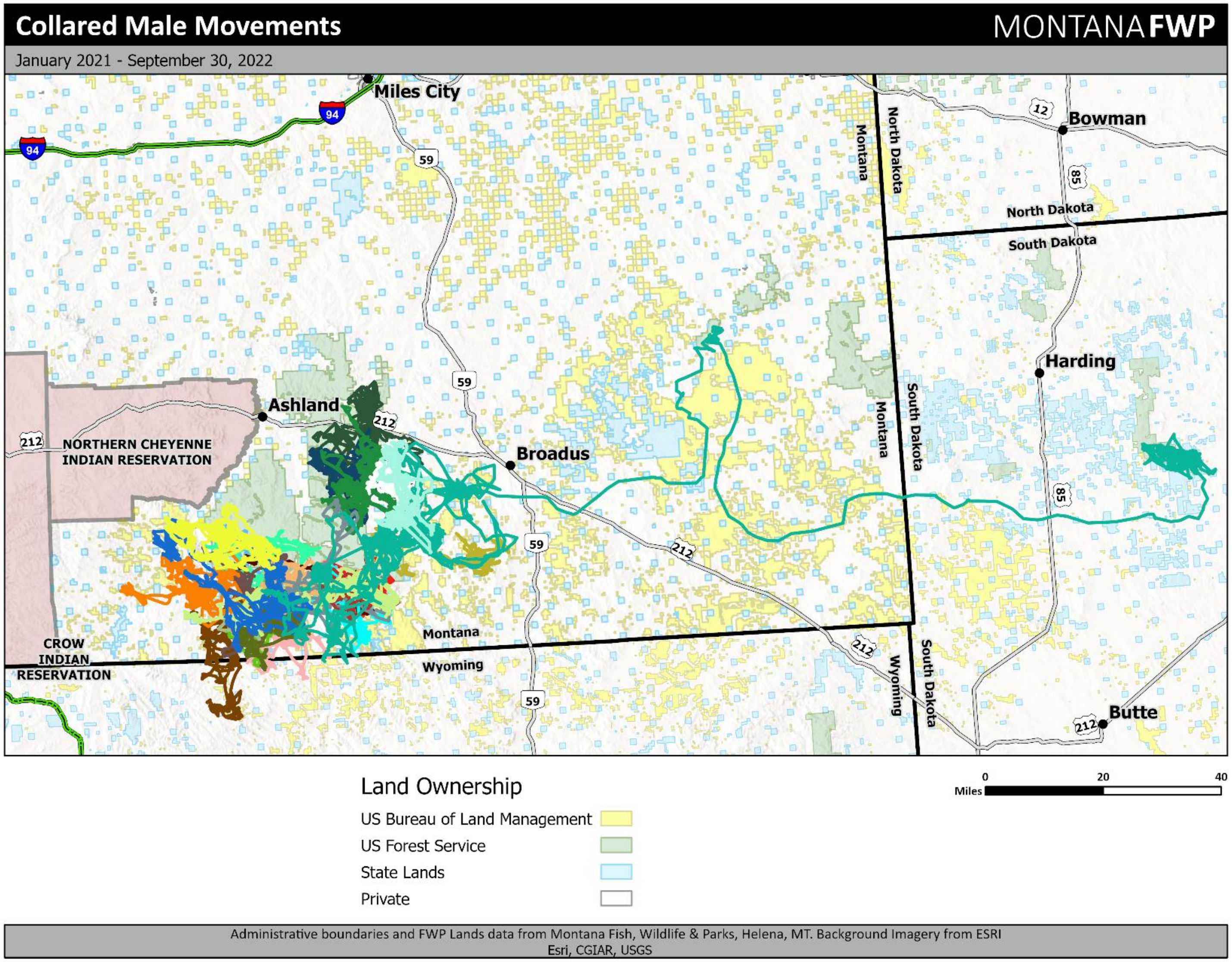


Figure 13. Movements of 25 collared males in the Custer study area through September 30, 2022.

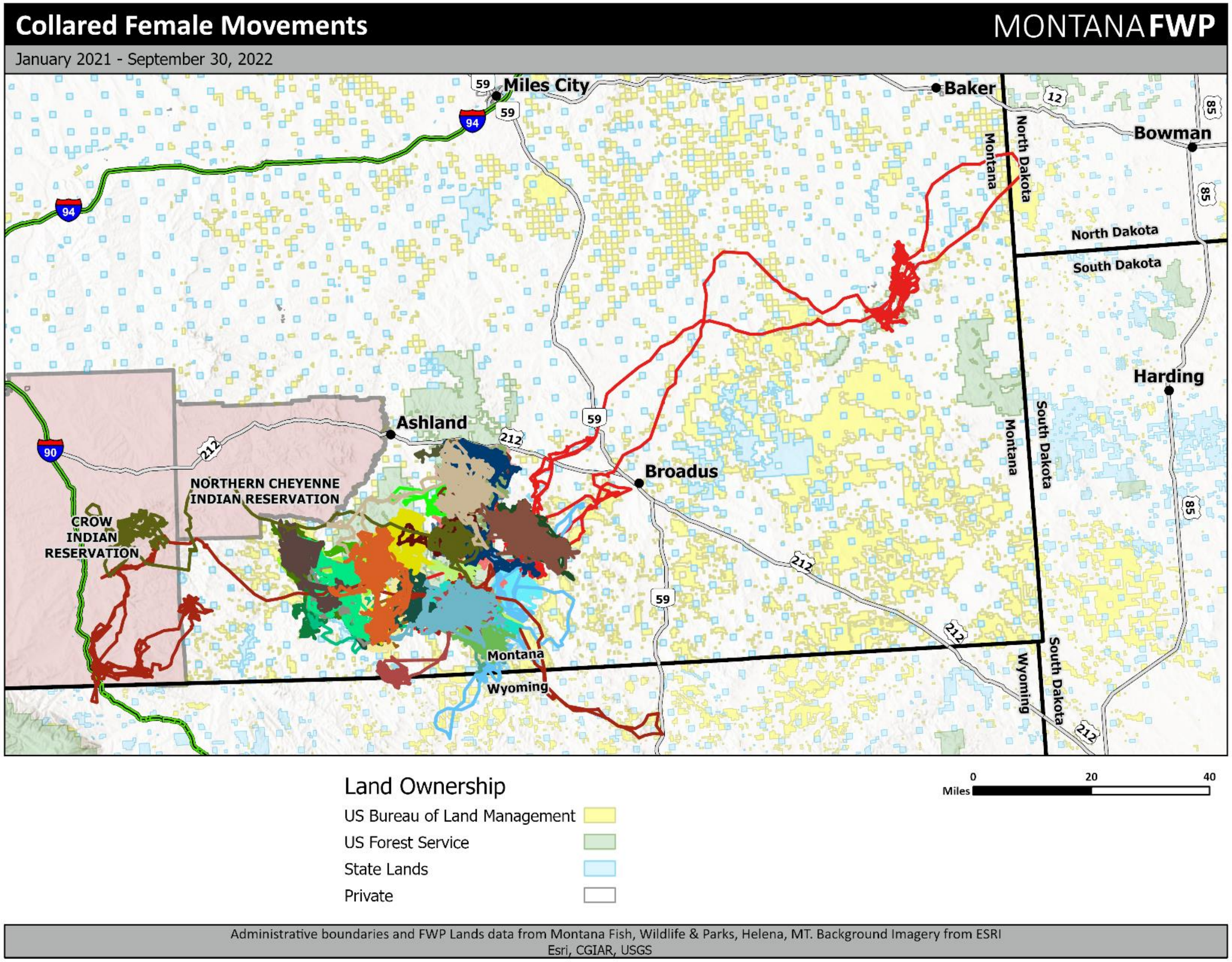
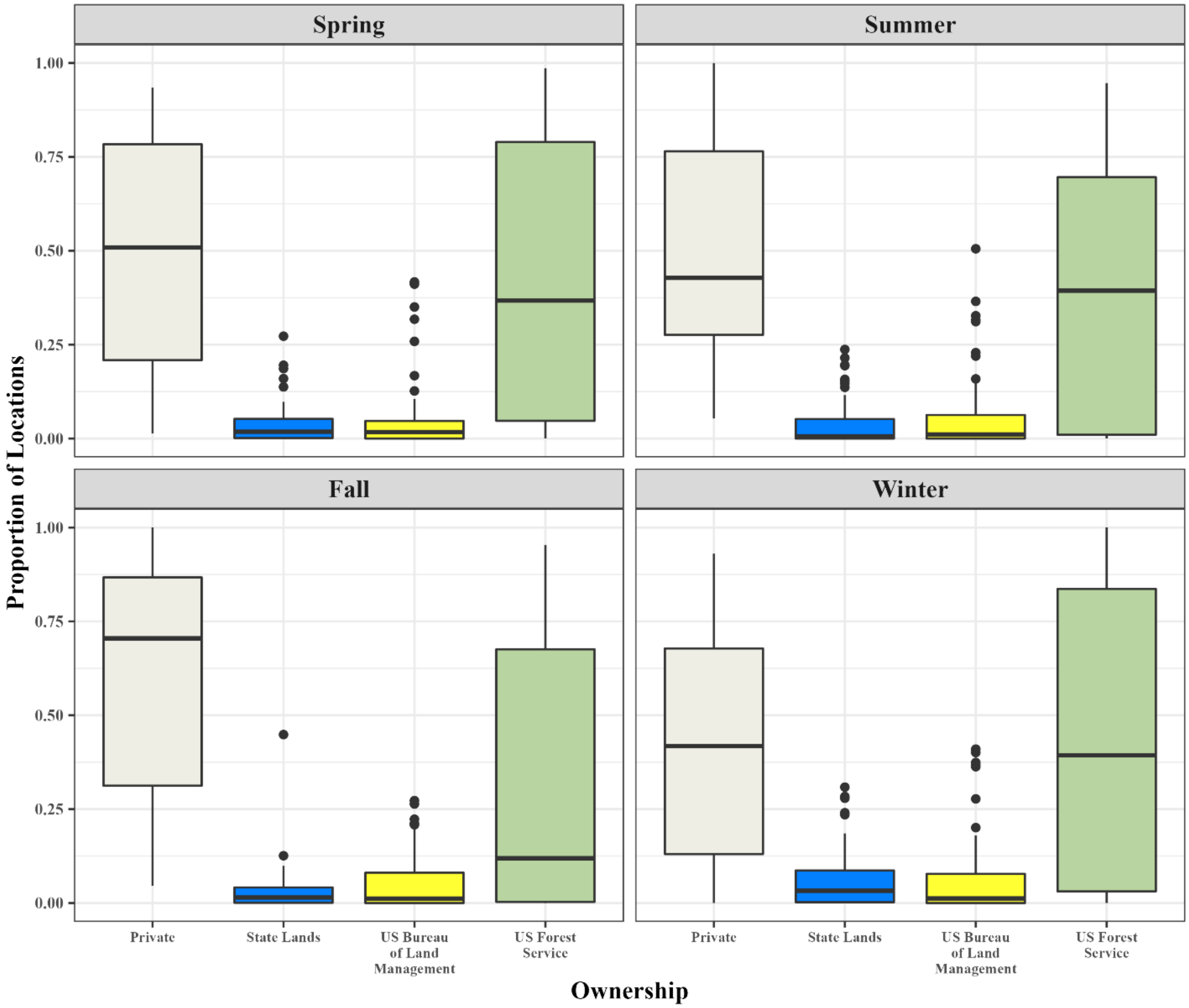


Figure 14. Movements of 44 collared females in the Custer study area through September 30, 2022

2.2.3 Custer Elk Land Use



'Private' refers to any lands that are not managed by the state of Montana, MTFWP, USFS, BLM, or USFWS

Figure 15. Proportional use of state, federal, and private lands by individual elk in the Custer study area by season.

2.3 Missouri Breaks Elk Location and Movement Data Collection

We have gathered 248,250 locations from 60 individuals in the Missouri Breaks study area for an average of 4,208 (range = 470-4,797) locations per individual. We have recorded 5 collar malfunctions and 3 mortalities; we are currently monitoring 52 individuals (14 males, 38 females). Monthly reports have been generated and distributed to regional MFWP staff as well as other agency partners, private landowners, and other members of the public. Preliminary estimates of seasonal ranges and movement corridors will be compiled after a full year of data collection and will be finalized when data collection is complete.

We have observed a variety of individual movement patterns in both male and female collared elk (Figures 16 and 17). Some individuals have displayed seasonally migratory behavior based on the presence of distinct summer and winter ranges. Other individuals have displayed behavior more characteristic of resident animals, with seasonal ranges that largely overlap. However, while distinct summer and winter ranges can be distinguished for some individuals, the distance travelled between seasonal ranges has been modest and relatively localized so far. The range of multiple male and female elk has extended across the Musselshell River on the western edge of the study area into elk hunting district 410. Three females have made brief movements across highway 200; this crossing location may offer opportunities for future conservation efforts if it can be identified as a consistent crossing location (Figure 17).

The location data collected in the Missouri Breaks area thus far indicates that elk primarily use privately owned lands (41% of locations) and lands managed by the BLM (35% of locations). Lands managed by the US Fish and Wildlife Service (20% of locations) and State of Montana (4% of locations) are used less frequently. The data collected so far indicate that BLM lands are an important component of elk habitat in the Missouri Breaks area. As in the Custer area, there is variation among individuals in patterns of land use, but a consistently large percentage of total locations across all seasons occur on BLM lands in this study area. Some collared individuals use BLM lands at much higher rates; a maximum of 90% of an individual's locations have occurred on BLM managed lands thus far. Patterns of the distribution of locations across land ownerships are similar across seasons, though on average, use of BLM lands appears to increase during the winter and spring and decrease during summer and fall (Figure 18).

2.3.1 Missouri Breaks Elk Locations and Movements

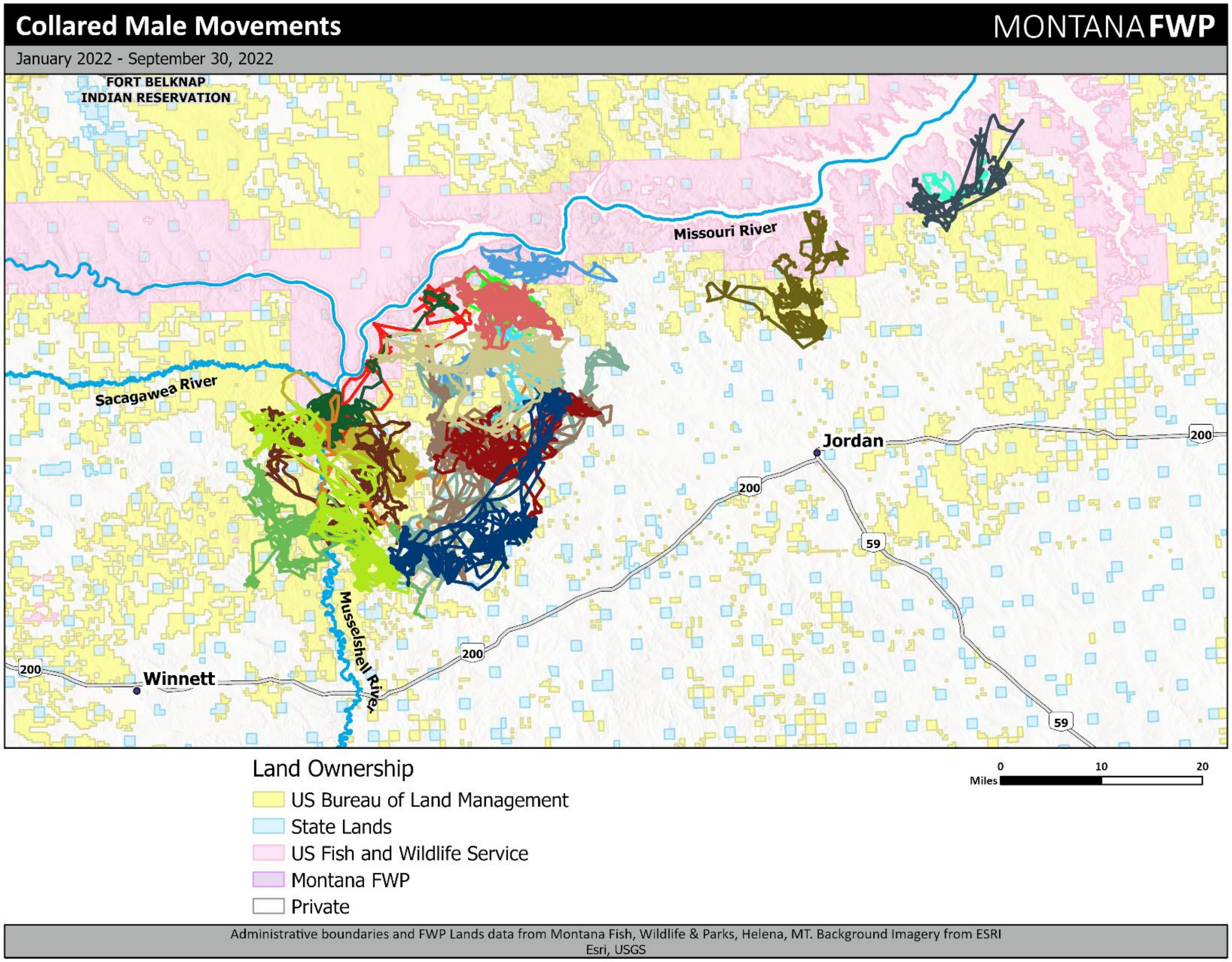


Figure 16. Movements of 20 collared males in the Missouri Breaks study area through September 30, 2022.

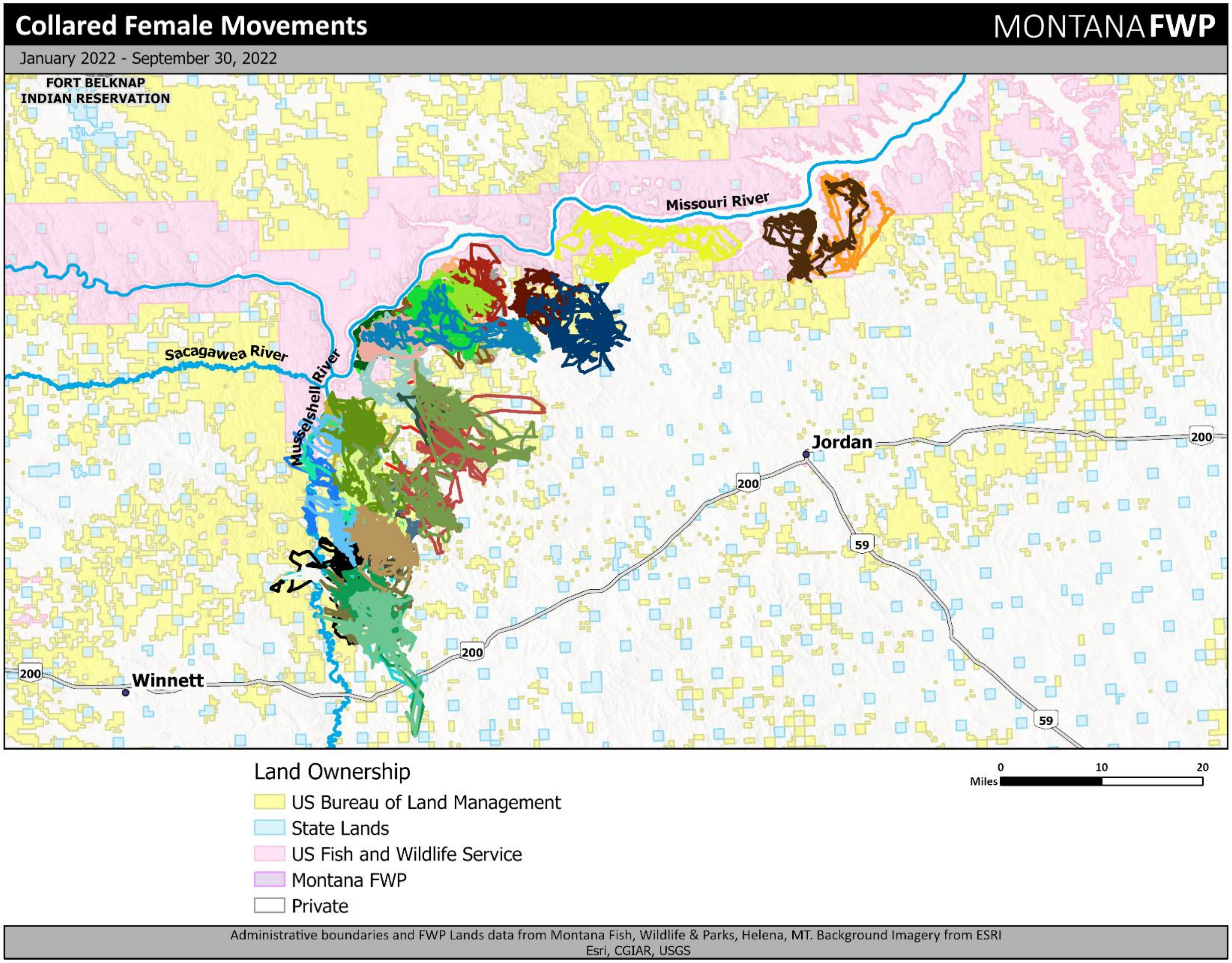
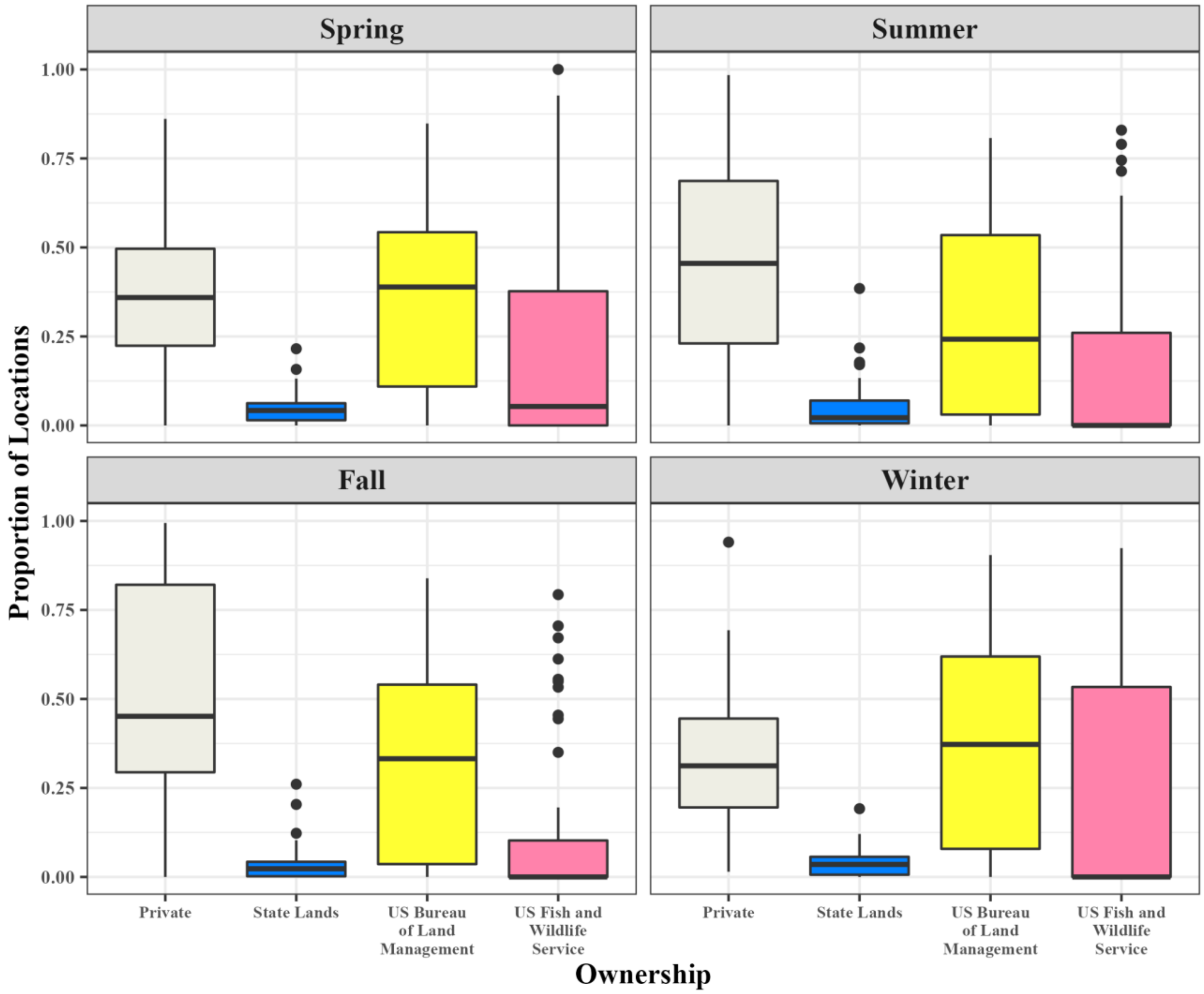


Figure 17. Movements of 40 collared females in the Missouri Breaks study area through September 30, 2022.

2.3.2 Missouri Breaks Elk Land Use



'Private' refers to any lands that are not managed by the state of Montana, MTFWP, BLM or USFWS

Figure 18. Proportional use of state, federal, and private lands by individual elk in the Missouri Breaks study area by season.

Objective 3: Begin work on state-wide analysis of factors associated with overabundant elk populations.

3.1 State-wide overabundance analysis

The purpose of this project is to evaluate landscape factors associated with overabundant elk populations and provide information to enhance management strategies aimed at achieving more desirable distributions and harvest management objectives. Many elk populations in Montana have exceeded the population objectives for their respective management units. Elk populations that are over objective across a management unit may be problematic due to their impact on stakeholders and the environment.

In non-harvested populations of large ungulates, adult female survival is fairly constant with variation in recruitment driving fluctuations in population growth (Gaillard et al. 1998) while in harvested populations adult female survival is more variable and has the capacity to alter population growth rates (Brodie et al. 2013) making the harvest of female elk the primary method for controlling elk population growth. Harvest of female elk can effectively curtail population growth and even have a residual effect in subsequent years by altering the age structure of a population if harvest targets are achieved (Paterson et al. 2022). However, the level of hunter harvest of elk in some areas has proven insufficient to effectively control elk population growth. This has been seen in Montana where many hunting districts (HD) are over their prescribed population objectives despite having regulations that allow for and encourage female elk harvest. Given that populations exceed their numerical objectives despite liberalized female harvest regulations, it is necessary to explore factors other than harvest regulations that may be limiting hunter efficacy in reducing female survival rates and in turn reducing problematic populations' growth rates.

Hunter harvest rates can be affected by several factors that vary spatially and temporally. The most influential variables include road access, elk abundance, the number of hunters per elk, and weather. Weather's effect on harvest success is highly specific to a given region or herd's response making generalizations as to the effect of weather on harvest success difficult (Cooper et al. 2002; Hansen et al. 1986). Recent research on elk distributions during the hunting seasons found that in addition to traditional security habitat (far from roads and timbered) elk are finding security on lands that restrict hunter access (DeVoe et al. 2019; Proffitt et al. 2013, 2016). These areas may be public lands that prohibit hunting (Mikle et al. 2019) or private lands not enrolled in access programs (hereon referred to as unknown access) where hunting pressure is lower as compared to public lands that permit hunting or private lands enrolled in access programs (hereon referred to as accessible). The effect of these areas of unknown access is two-fold limiting harvest on large swaths of land and drawing elk away from accessible lands where hunting pressure is greater. Successful reduction of problematic elk populations to within objectives is not possible if elk distributions during the hunting season limit the total harvest of females. Given the current abundance of problematic elk populations, there is a need to identify the characteristics of HDs with overabundant populations to identify management tools that may be effective in managing these populations toward objective size. The objective of this study is to evaluate factors associated with overabundant elk populations. We will evaluate the effects of factors such as security habitat, hunter access, and landscape variable on two response variables representing attributes of overabundant elk populations: 1) the proportion over or under objective levels and 2) the population growth rate. For each HD, we estimated the proportion over or under objective as the current count/ objective number and we estimated the growth rate using an integrated population model.

We have assembled all the available elk count, elk harvest and elk population objective information from Montana hunting districts in administrative regions 2-7 (Table 2). Region 1 lacked sufficient elk count data and was censored from analysis. Each district has been described as the objective number of elk per km^2 of habitat and hunter effort per km^2 of habitat, where kilometers of habitat was defined by the FWP elk distribution layer. These quantitative descriptions of hunting districts have been used in a preliminary analysis describing what factors are correlated with a hunting district's objective status. We have initiated the development of spatial data to use in our analysis of factors associated with problematic distributions including the proportion of a district that is security habitat, accessible to the public for hunting, and agriculture or pasture. We developed a state-wide road layer that allows for definition of road access based on the season. This layer was used to identify security habitat as it varies between archery and rifle seasons.

To estimate population growth rates, we have initiated the development of an integrated population model (IPM). The IPM incorporates two models, a process model describing the biological processes underlying the population dynamics and an observational model that connects elk survey data to the biological processes. The process model estimates elk adult survival and annual calf recruitment rates across all hunting districts, with individual district variation in harvest as estimated by the annual harvest survey. The observational model uses Poisson and multinomial distributions to estimate each hunting district's total population and bull, calf, and cow classifications respectively given the annual survey observations and the process model. Once complete, the model will be used to estimate the population growth rates for each hunting district.

Table 2. The population objective number of elk and hunter effort per km2 of elk habitat (average number of hunter days per season 2004-2020) per hunting district. The area of habitat per hunting district was based on the Montana Fish, Wildlife, and Parks (MFWP) elk distribution layer.

Hunting District	Objective Elk Per Km^2	Hunter Days Per Km^2	Area of Habitat (Km^2)
200	0.49	3.01	712
201	0.44	3.23	649
202	0.19	1.67	941
203	0.90	2.57	611
204	0.56	2.48	974
210	0.81	4.11	686
211	0.70	2.23	2,678
212	0.34	2.77	563
213	1.61	7.64	1,358
214	0.95	2.85	1,560
215	1.16	7.15	1,852
216	0.42	1.72	375
240	0.52	2.24	1,359
250	0.77	0.29	1,096
261	1.14	2.97	2,050
270	2.53	6.21	1,181
281	0.62	3.88	1,106
282, 285	0.73	0.42	1,677
283	0.76	2.93	631
290, 298	0.88	1.12	1,179
291	0.77	2.97	6,104
292	0.78	3.80	663
293	0.68	3.53	810
300	1.21	6.22	859
301, 309	0.56	2.87	1,553
302	0.77	3.44	696
310, 360	2.15	3.28	713
311	2.36	4.59	1,503
312	0.84	4.99	1,929
313	6.16	5.21	1,205
314	2.57	3.80	896

Hunting District	Objective Elk Per Km^2	Hunter Days Per Km^2	Area of Habitat (Km ^{2})
315	0.99	4.36	1,365
317	0.97	3.23	1,169
318	0.70	6.48	1,052
319	0.86	4.33	903
320, 333	0.49	1.33	867
322 - 327, 330	1.31	0.38	3,573
328	0.99	2.90	1,174
329	0.71	4.07	1,029
331	0.83	3.38	1,059
332	0.53	2.26	1,099
335	1.07	7.65	612
339, 343	1.00	1.53	518
340	0.78	5.54	474
341	1.22	5.85	465
350, 370	0.59	3.04	930
360, 361, 362	2.03	2.65	1,021
380	1.35	6.90	1,061
390	1.47	5.02	767
391	1.00	6.49	1,066
392	0.38	3.14	1,007
393	1.36	4.37	968
401	0.26	0.88	174
410	0.80	2.67	429
411, 511, 530	0.28	1.79	514
412	0.29	1.75	1,601
413	0.44	2.04	1,125
415	0.39	0.88	539
416	0.42	4.08	778
417	0.23	1.18	1,501
418	0.40	2.17	2,899
420, 448	1.19	0.90	790
421, 423	0.53	0.86	544
422	0.58	1.69	1,009
424, 425, 442	1.76	0.49	941
426	0.14	2.07	1,018
432	0.37	2.70	1,285
441	0.58	1.55	1,423

Hunting District	Objective Elk Per Km^2	Hunter Days Per Km^2	Area of Habitat (Km ^{2})
455, 445	1.67	1.12	952
446	0.81	2.61	1,482
447	0.74	2.63	2,311
449, 452	0.76	1.58	864
450	0.50	2.77	1,394
454	0.46	4.63	615
500	0.11	2.99	1,111
502, 520, 575	0.48	0.24	1,064
540	1.05	4.69	1,827
560	0.33	1.29	858
570	0.11	1.78	1,132
580	0.58	2.30	1,054
621, 622	0.43	0.58	2,148
631, 632	0.30	0.67	569
680, 690	0.23	0.18	5,860
700, 701	0.04	0.81	2,786

Objective 4: Begin work on habitat selection analysis in the Devil's Kitchen study area.

4.1 Devil's Kitchen habitat selection analysis

The population dynamics of elk and other large ungulate species are largely driven by adult female survival rates (Gaillard et al. 2000, Eacker et al. 2017), and the primary tool available to reduce survival rates and manage overabundant populations is the liberalization of adult female harvest regulations (Sinclair et al. 2006, Loe et al. 2016, Gruntorad and Chizinski 2020). However, when elk distributions overlap private lands, reducing elk abundance through hunter harvest can be challenging (Haggerty and Travis 2006, Proffitt et al. 2016). While the wildlife on private lands is a public resource managed in the public trust by state wildlife managers (Mahoney and Geist 2019), public access to private lands for hunting is provided at the discretion of individual landowners. Where overabundant elk populations and private lands overlap, the success of hunter harvest as a tool for elk population management depends not only on the harvest regulations applied, but also on the availability of hunting access on private lands.

While many have shown that elk preferentially select for areas that restrict hunting access where available (Burcham et al. 1999, Conner et al. 2001, Proffitt et al. 2010, Proffitt et al. 2013, Sergeyev et al. 2020), our understanding of the factors that influence selection for or against strategies of hunter access remains limited. The objectives of this study are to (1) evaluate the effects of hunting period, harvest regulation, hunter harvest, migratory behavior, and landscape features on female elk selection of hunter access management strategy during the hunting season, and (2) forecast the consequences of potential changes in harvest regulations on elk distributions and harvest risk. We have developed a database of hunter access management strategies by classifying individual land parcels in the study area into discrete categories (open, controlled, and restricted access) based on personal communication with local land and wildlife managers and private landowners (Figure 19). We classified a parcel as open access if publicly owned and accessible or privately-owned and enrolled in Montana's Block Management Access (BMA) system and not requiring a reservation to hunt. A parcel was categorized as controlled access if landowners allowed access to members of the public who enquired, or if it was enrolled in the BMA program but required a reservation which limited the number of hunters. Parcels were classified as restrictive access if landowners allowed access only for friends and family or outfitted clients, or if no public hunting opportunities were available. Publicly owned but landlocked parcels were classified using the access management strategies of surrounding private lands (Figure 2).

We have also developed a suite of five covariates including a categorical variable of hunting period based on the legal open/close dates of each portion of the fall hunting season, a categorical variable of hunting regulation based on the availability of tags in each hunting district (Table 3), an estimate of hunter harvest based on MFWP hunter harvest survey phone calls, a binary classification of migratory behavior based on overlap of individual seasonal core use areas, and a quantitative variable of snow water equivalent (SWE) that quantified cumulative snowfall during the hunting season.

We fit a series of Bayesian multistate models to evaluate the factors influencing the probability that an elk transitioned between hunter access types during the fall hunting season. We pooled hunting season locations from licensing years 2020 and 2021 and ran 6 separate models (1 for each of the five covariates described above and an intercept-only model). Each model tested a different hypothesis about the factors influencing the probability that an elk made a transition from one hunter access class to another. We used WAIC to compare models and rank them based on model fit (Table 4). WAIC comparisons showed that the model containing hunting period produced the best fit to the observed data of the covariates we investigated.

With notable exceptions, the probability that an elk stayed in the same access class on day *t+1* as on day *t* tended to be higher than the probability of transitioning into a different access class on day *t+1* in any given hunting period (Figure 20). Elk were on average more likely to stay in areas of open access and less likely to stay in controlled access or restrictive access during the general rifle period. On average, elk were more likely to transition into Controlled Access when in Restrictive Access the previous day during the general rifle hunting period. In the late shoulder period, elk were less likely to stay in areas of Open Access and more likely to transition out of Open Access and into Restrictive Access relative to other hunting periods. We plan to finalize this analysis on schedule during the next reporting period and will share results with stakeholders during public meetings and through publications available on the FWP website and in a scientific journal.

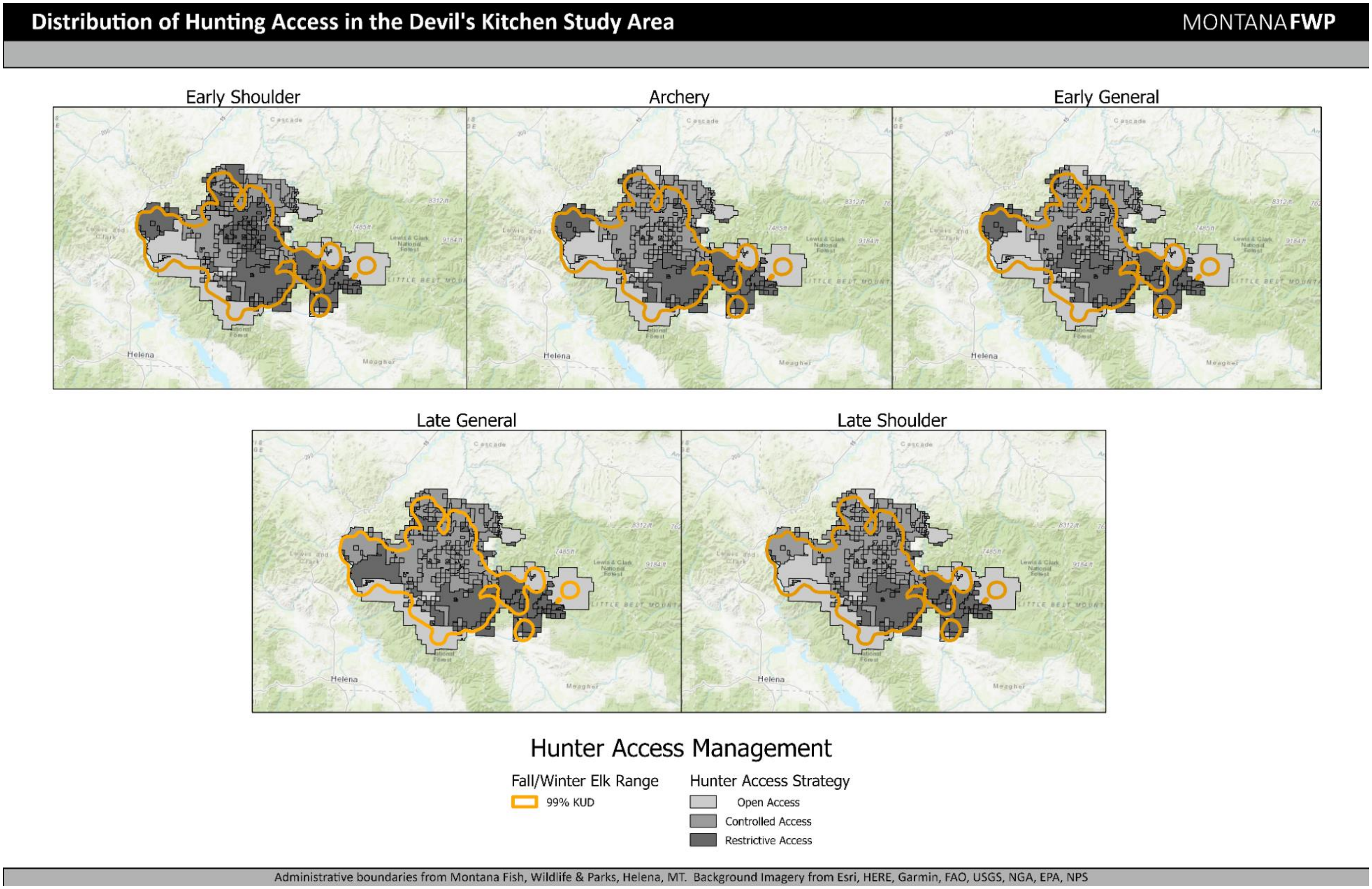


Figure 19. The distribution of hunter access classes in relation to a 99% kernel utilization distribution (KUD) of fall/winter elk locations. We defined open access as publicly accessible public lands or private lands enrolled in Montana's block management access program (BMA) and not requiring a reservation to hunt. We classified controlled access as areas where landowners granted access to members of the public who enquired or were enrolled in the BMA program but required a reservation. Parcels were classified as restrictive access if landowners allowed access only for friends and family or outfitted clients, or if no public hunting opportunities were available. Publicly owned but landlocked parcels were classified using the access management strategies of surrounding private lands. Devil's Kitchen study area, central Montana, USA, 2021—2022.

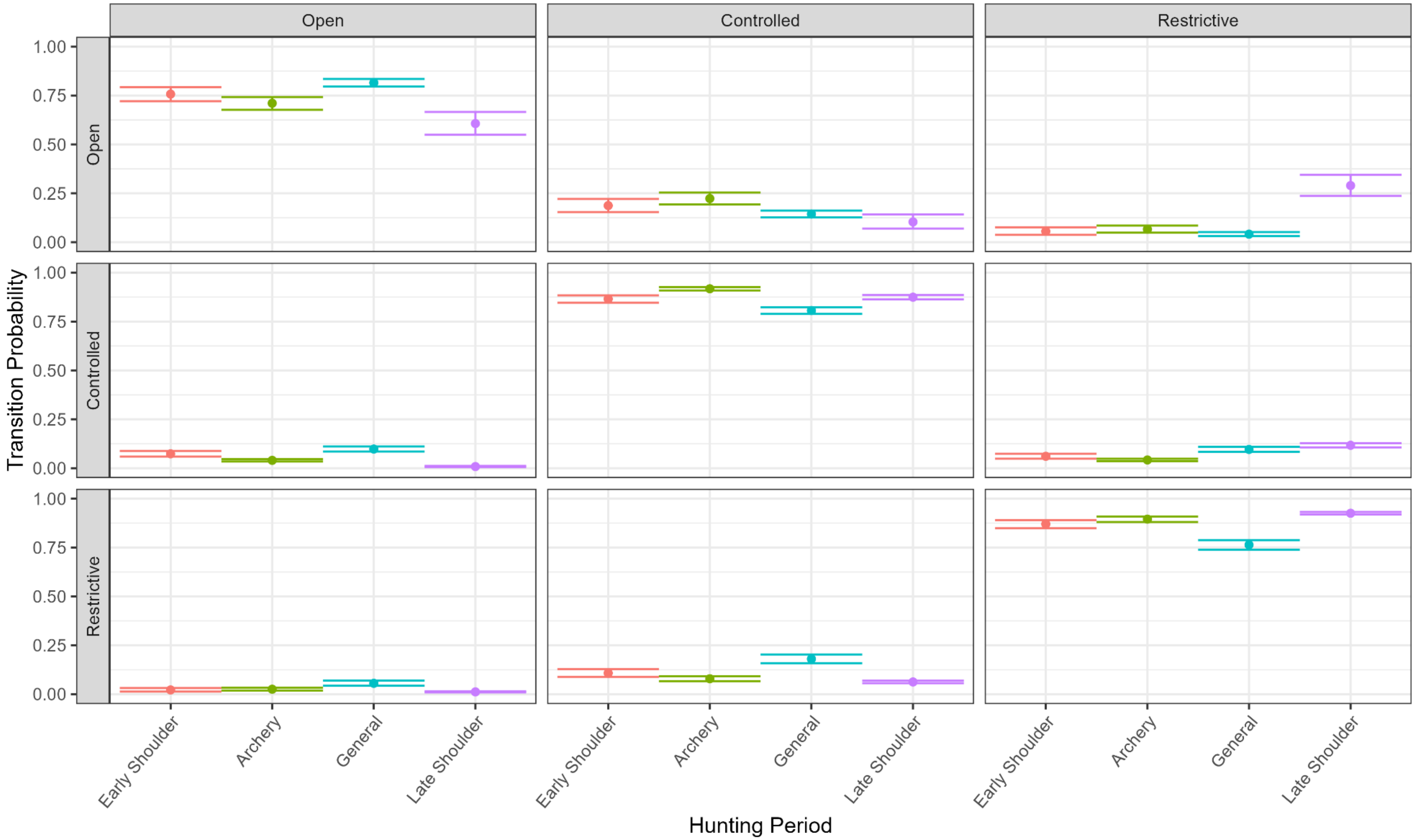


Figure 20. Results from the top-performing matrix model with hunting period included as a covariate. Points indicate posterior mean estimates of the probability of transitioning from an access class on day t (left side panel) to an access class on day t+1 (top panel). With notable exceptions, the probability that an elk stayed in the same access class on day t+1 as on day t tended to be higher than the probability of transitioning into a different access class on day t+1 in any given hunting period. Elk were on average more likely to stay in areas of open access and less likely to stay in controlled access or restrictive access during the general rifle period. Elk were on average more likely to transition into controlled access when in restrictive access the previous day during the general rifle hunting period relative to other periods of the hunting season. In the late shoulder season, elk were less likely to stay in areas of open access and more likely to transition out of open access and into restrictive access relative to other hunting periods.

Table 3. Hunting regulations effective in the Devil's Kitchen study area, central Montana, USA, 2021-2022. General licenses were valid across the state for the harvest of one elk depending on unit-specific regulations. Individuals could only purchase a single general license each year but there was no quota on the total number available for purchase by resident hunters. Elk B-Licenses were only valid for the harvest of antlerless elk. An annual quota of 6,000 B-license 004-00, 25 B-License 392-00, and 250 B-License 455-00 were available during the study period. A hunter in possession of a General License could purchase 2 B-Licenses in a given year. Elk permits were only valid with a General License and were allocated through a drawing. A quota of 45 Permit 445-20, 75 Permit 455-20, and 4,000 Permit 900-20 were available annually during the study period.

District	Hunt Period	License Type	Harvest Regulation	Regulation Class
392	Early Shoulder	--	No Harvest	No Harvest
	Archery	General License	Brow-tined Bull or Antlerless	Liberal
		B-License 392-00	Antlerless Only	
	Early General	General License	Brow-tined Bull	Restrictive
		B-License 392-00	Antlerless Only	
	Late General	General License	Brow-tined Bull	Restrictive
		B-License 392-00	Antlerless Only	
	Late Shoulder	--	No Harvest	No Harvest
413	Early Shoulder	--	No Harvest	No Harvest
	Archery	General License	Either-sex	Liberal
		B-License 004-00	Antlerless Only	
	Early General	General License	Either-sex	Liberal
		B-License 004-00	Antlerless Only	
	Late General	General License	Either-sex	Liberal
		B-License 004-00	Antlerless Only	
	Late Shoulder	--	No Harvest	No Harvest
416	Early Shoulder	--	No Harvest	No Harvest
	Archery	General License	Either-sex	Liberal
		B-License 004-00	Antlerless	
	Early General	General License	Either-sex	Liberal
		B-License 004-00	Antlerless	
	Late General	General License	Either-sex	Liberal
		B-License 004-00	Antlerless	
	Late Shoulder	--	No Harvest	No Harvest
445	Early Shoulder	General License	Antlerless	Liberal
		B-License 004-00	Antlerless	
	Archery	General License	Either-sex	Liberal
		B-License 004-00	Antlerless	
		Permit 445-20	Either-sex	
	Early General	General License	Either-sex	Liberal
		B-License 004-00	Antlerless	
		Permit 445-20	Either-sex	
	Late General	General License	Antlerless	Liberal
		B-License 004-00	Antlerless	
		Permit 445-20	Either-sex	
	Late Shoulder	General License	Antlerless	Liberal
		B-License 004-00	Antlerless	

Table 3. Continued

District	Hunt Period	License Type	Harvest Regulation	Regulation Class
446	Early Shoulder	General License	Antlerless	Liberal
		B-License 004-00	Antlerless	
	Archery	General License	Brow-tined Bull or Antlerless	Liberal
		B-License 004-00	Antlerless	
	Early General	General License	Brow-tined Bull or Antlerless	Liberal
		B-License 004-00	Antlerless	
	Late General	General License	Brow-tined Bull or Antlerless	Liberal
		B-License 004-00	Antlerless	
	Late Shoulder	General License	Antlerless	Liberal
		B-License 004-00	Antlerless	
455	Early Shoulder	--	No Harvest	No Harvest
	Archery	Permit 455-20	Either-sex	Restrictive
		Permit 900-20	Either-sex	
		B-License 455-00	Antlerless	
	Early General	Permit 455-20	Either-sex	Restrictive
		B-License 455-00	Antlerless	
	Late General	Permit 455-20	Either-sex	Restrictive
		B-License 455-00	Antlerless	
	Late Shoulder	--	No Harvest	No Harvest

Table 4. Results of WAIC comparison of candidate multi-state models. ΔWAIC values indicate the difference between each candidate model's WAIC score and that of the top performing model. The top-performing model in our candidate suite included Hunt Period as an explanatory predictor. Devil's Kitchen study area, central Montana, USA, 2021—2022.

Model	WAIC	ΔWAIC
Hunt Period	14450.55	0.00
Hunting Regulation	14566.66	-166.11
Hunter Harvest	14846.05	-395.50
Migratory Status	14994.99	-544.44
Constant/Null	15013.08	-562.53

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