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Pronghorn Movement and Population Ecology

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Executive Summary

The Montana Pronghorn Movement and Population Ecology Project was initiated in 2020 to collect information on pronghorn movements, seasonal habitat use, and demographics in 7 study areas across Montana that included the Big Hole, Paradise, Musselshell, Fergus-Petroleum, South Philips, Garfield-Rosebud, and Powder River-Carter study areas. An ongoing pronghorn study collecting identical information in the Madison that began in 2019 is being included in this study and reporting. The primary objectives of the project are to: 1) delineate pronghorn seasonal range and movement corridors in the study areas; 2) distribute maps of seasonal range and movement corridors to conservation partners and landowners via a web-based platform; 3) use seasonal range and movement data to identify potential barriers to movements, inform management decisions, and prioritize locations for habitat improvement projects; 4) develop a population model to identify important vital rates affecting population growth rates and describe important demographic differences between pronghorn populations that are growing or stable, versus those that are limited in their population performance, and 5) evaluate the effect of vegetation and other landscape features on resource selection and movement of migratory and non-migratory pronghorn.

In February 2022, we captured and instrumented with GPS collars a total of 104 adult female pronghorn to augment the sample of animals captured in winters 2020 (n = 390) and 2021 (n = 168) and maintain approximately 60 animals with active collars in each study area. This capture effort included a total of 8 in the Paradise, 9 in the South Philips, 12 in the Big Hole, 13 in the Garfield-Rosebud, 15 in the Fergus-Petroleum, 23 in the Powder River-Carter, and 24 in the Musselshell study areas. In total, across all study areas from 2019 to 2022, we captured and collared 702 animals. To date, across all study areas, a total of 45 collars have malfunctioned, 263 animals have died, and 394 collars remain active and will continue to be monitored until February 2023. We have collected 8,055,574 locations from 702 individuals. Monthly survival probabilities in each population remained relatively stable from 2020 – 2022, ranging 0.87 (95% credible interval [CRI] 0.73 – 0.96) to 0.97 (CRI 0.92 – 1.00). Annual survival probabilities ranged from 0.66 (CRI 0.53 – 0.77) in 2021 for the Powder River-Carter to 0.83 (CRI 0.73 – 0.92) in 2021 for the Madison.

Movement patterns of individuals were diverse within and across study areas with population-level seasonal ranges generally reflecting greater contraction from summer to winter in the montane-valley populations of southwest Montana as compared to the prairie populations of central and eastern Montana. On a monthly basis, we generate study area-specific summary reports of collared pronghorn movements and mortality information and distribute these reports widely to state and federal agency biologists, non-profit conservation organizations, and private landowners. We developed a web interface that allows biologists to view pronghorn movement trajectories and identify areas that may be barriers to pronghorn movements. FWP leadership will determine how additional web-based data sharing will proceed. Fence mapping projects have been initiated in all study areas and are being aggregated into a single spatial layer for mapping, movement barrier identification, and evaluation of the influence of fences on pronghorn movements and behaviors.

We have used the collar location data in combination with the fence spatial data to evaluate the influence of different fence types of pronghorn behavioral responses, which provides evidence for the prioritization of woven wire fence removal or replacement to more permeable fence types. We also implemented a tool to identify and quantify pronghorn behavioral responses to fences that outputs interactive maps ranking fences based on these responses, which can be used to identify problematic barriers to pronghorn movement and prioritize remediation efforts.

We have continued development of the integrated population model (IPM) to 1) identify important vital rates affecting population growth rate, 2) contrast important vital rates among populations, and 3) develop hypotheses to explain why some pronghorn populations experience limitations on population growth rate. We developed a dataset of pronghorn population size and harvest, compiled priors and potential covariates that will be used in the IPM, and have begun model development. The IPM will be completed and presented in the next reporting period.

Finally, we sampled vegetation and pronghorn fecal pellets from mid-March to July 2021 and 2022 in three central Montana study areas (Musselshell, Fergus-Petroleum, and South Philips) to understand how seasonal changes in forage resources affect pronghorn resource selection and movements. We collected vegetation data at a total of 578 locations, including 287 at known locations of collared pronghorn and 291 at available locations randomly distributed in proportion to landcover type. In addition, we collected a total of 45 fecal samples each year during multiple sampling periods across the summer for diet analysis. Sampling efforts for this portion of the project have concluded and the analysis is in development.

Project Background

Pronghorn (*Antilocapra americana*) provide important ecosystem functions and recreational opportunities in Montana, which hosts the 2nd largest population and harvest of pronghorn across their range. Ecologically, pronghorn may serve as an umbrella species for conserving sagebrush-grasslands and maintaining landscape connectivity of these systems (Rowland et al. 2006, Gates et al. 2012). Because of the important ecosystem functions and recreational opportunities pronghorn provide, conserving and managing pronghorn and their habitats is a priority for Montana Fish, Wildlife & Parks (FWP), land management agencies, private landowners, non-governmental organizations (NGOs), and numerous additional stakeholders.

Recently, there has been a focus in the western United States to identify and protect big game migration corridors and winter ranges, highlighted in the 2018 Department of Interior Secretarial Order (SO) 3362. The purpose of SO 3362 is to foster collaboration between the federal government, states, NGOs, and private landowners to identify, improve, and conserve winter range and migration corridors for mule deer, elk, and pronghorn. In response to SO 3362, FWP drafted a State Action Plan which identifies five priority conservation areas in Montana. Collaborations between landowners and state and federal wildlife, land management, and transportation agencies have since formed to design cooperative habitat or transportation projects to improve landscape connectivity and conserve big game populations.

In Montana, there are limited data available regarding pronghorn movements and population dynamics. Therefore, additional information is needed regarding pronghorn seasonal habitat use and migratory movements to inform and prioritize these important habitat and conservation efforts. In addition to collecting movement data, understanding population demography is needed to promote effective management strategies. Given widespread pronghorn population declines in portions of central and eastern Montana in recent decades, biologists need information regarding survival and demography to identify and understand potential issues limiting pronghorn population recovery.

Pronghorn populations were abundant and at or above regional population objectives/long-term averages (LTAs) throughout their range in Montana during the mid-2000s with harvest totaling 33,500 at the latest peak in 2007. Following widespread blue-tongue virus (BTV) outbreaks in the subsequent two years, then the record cold and snowy winter in 2010-2011, harvest fell to a low of 8,200 in 2013 (Montana Fish Wildlife and Parks 2020*a*). Pronghorn populations typically rebound quickly with favorable weather conditions, yet numbers of pronghorn in many of Montana's central and eastern populations are < 50% of population objective despite multiple years of favorable weather and minimal harvest. Meanwhile, mule deer and elk populations are exceeding objective levels over much of the region (Montana Fish Wildlife and Parks 2020*b*, *c*)

The factors currently limiting pronghorn population recovery across central and eastern Montana are unknown. Stochastic events including severe winter weather may cause significant mortality events, leading to high variability in overwinter pronghorn survival rates (Martinka 1967, Pyrah 1987, O'Gara 2004*a*). Accordingly, survival of adult female pronghorn is lower or more variable than for other northern temperate ungulates, ranging from 0.29 to 0.87 in Montana (Boccadori 2002, Dunn and Byers 2008, Barnowe-Meyer et al. 2009, Jakes 2015). During winter 2010-2011, abnormally high snow depths in central and eastern Montana concentrated pronghorn on winter range, resulting in rapid exhaustion of browse, over-exposure of pronghorn to extreme conditions, and altered pronghorn distributions (Jakes et al. 2018*a*). In the Fort Peck Reservoir area of central Montana, flooding exacerbated the effects of the 2011 severe winters, as more than 2,000 pronghorn attempting to return north to fawning and summer ranges were stranded on the south side of the reservoir by unusually high floodwaters and were presumed to have died after exhausting nearby forage. Fences and roads may also act as barriers to movements within or between seasonal ranges, potentially affecting seasonal range selection and reducing habitat availability (Jakes et al. 2018*b*, Jones et al. 2019).

Pronghorn pregnancy and birth rates are generally high; however, these vital rates may also be affected by habitat or weather conditions and have the potential to limit pronghorn population recovery. Dunn and Byers (2008) recorded pronghorn reproductive failures on the National Bison Range (NBR), Montana, following severe drought in 2003 and none of the marked females that weaned fawns in 2003 gave birth in 2004. During this same period, annual counts of other ungulates on the NBR did not indicate exceptionally low survival or fecundity rates potentially because other ungulate species fall lower on the maternal energy-expenditure spectrum than pronghorn (Dunn and Byers 2008). Additionally, severe weather, such as drought or harsh winters, may have carryover effects on future reproductive success or survival (Webster et al. 2002). Although habitat or weather-related factors generally have a greater effect on pronghorn populations than predation, predation may limit recruitment and have important effects on population growth (O'Gara and Shaw 2004). Overall fawn mortality across 18 studies averaged 71%, with 76% of all mortalities being due to predation from coyotes (O'Gara and Shaw 2004). We expect that coyote predation is the main proximate cause of mortality of pronghorn fawns in central and eastern Montana, but its extent may vary due to habitat conditions (weather and land-use influences on vegetation), the abundance of alternate prey species (Hamlin and Mackie 1989, Berger and Conner 2008, Berger et al. 2008), or coyote control operations (Harrington and Conover 2007, Brown and Conover 2011).

In addition to the potential limiting effects of habitat, weather and predation on pronghorn survival and recruitment, disease events like BTV or epizootic hemorrhagic disease (EHD) can also impact pronghorn populations via direct mortality or negative effects on reproduction (Thorne et al. 1988, Dubay et al. 2006, Gray 2013). In July 2007, a BTV outbreak occurred across portions of central and eastern Montana and precipitated the decade-long decline in pronghorn populations (Montana Fish Wildlife and Parks 2012). Disentangling the effects of BTV and other diseases on pronghorn reproductive rates requires serologic assays and pregnancy tests or other measures of productivity in years with and without disease outbreaks, and data from pronghorn in this study will begin to inform us on the influences of disease on pronghorn populations in Montana.

Several hypotheses exist concerning factors potentially limiting pronghorn population recovery. For example, 1) adult female survival and/or recruitment, as influenced by weather, habitat conditions, predation, and/or a combination of these factors, may be too low and therefore limiting the population, 2) carryover effects of past disease events or current infection may impact adult female survival and reproduction, and/or 3) potential barriers restricting seasonal movements of pronghorn may impact vital rates. We will develop an integrated population model using adult female survival data combined with population abundance and production estimates from survey and harvest data. This population model will 1) identify important vital rates affecting population growth rate, 2) contrast important vital rates between populations that are considered productive vs. limited in performance, and 3) develop hypotheses to explain why some pronghorn populations experience limitations on population growth rate. The population model will provide information towards developing more focused investigations into ecological and/or anthropogenic factors limiting pronghorn population recovery in central Montana and future population monitoring strategies.

The overall purpose of this project is to identify seasonal ranges and movement corridors and provide demographic data for pronghorn populations in 8 study areas across Montana (Figure 1). These areas have been selected based on local needs identified by FWP area biologists and where considerable community, conservation partner, and agency interest exists in mapping anthropogenic impediments or other habitat features that influence habitat/migratory pathway selection or fitness. Our specific objectives include:

1. Delineate seasonal range and migration corridors of pronghorn in the study areas.
2. Distribute maps of seasonal range and movement areas for pronghorn widely to conservation partners and landowners via a web-based platform.
3. Use seasonal range and movement data to identify potential barriers to movements, inform management decisions, and prioritize locations for habitat improvement projects.
4. Develop a population model to identify important vital rates affecting population growth rates and describe important demographic differences between pronghorn populations that are growing or stable, versus those that are limited in their population performance.
5. Evaluate the effect of vegetation and other landscape features on resource selection and movement of migratory and non-migratory pronghorn.

Study Location

The 8 study areas are located in the southwestern, central, and southeastern regions of Montana (Figure 1) and include the Big Hole, Madison, Paradise, Musselshell, Fergus-Petroleum, South Philips, Garfield-Rosebud, and Powder River-Carter.

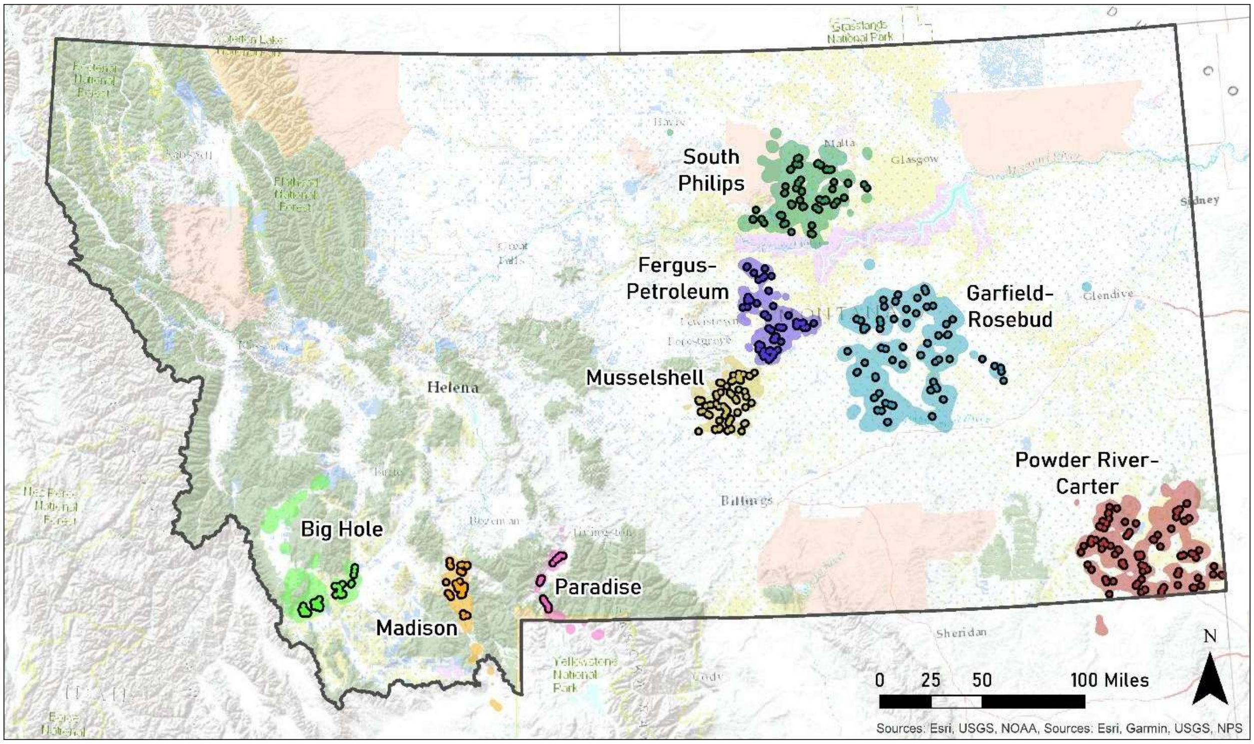


Figure 1. Locations of all adult female pronghorn captured and instrumented during winters 2019 – 2022 in the 8 study areas for the Montana Pronghorn Movement and Population Ecology Project. Study areas are represented by annual ranges calculated from 95% kernel density estimates based on collar locations collected 2019 - 2022.

Objective #1: Delineate seasonal range and migration corridors of pronghorn in the study areas

1.1 Capture and instrumentation

In February 2022, we captured and instrumented with GPS collars a total of 104 adult female pronghorn to augment the sample of animals captured in winters 2020 (n = 390) and 2021 (n = 168) and maintain approximately 60 animals with active collars in each study area (Figure 1). This most recent capture effort included a total of 8 in the Paradise, 9 in the South Philips, 12 in the Big Hole, 13 in the Garfield-Rosebud, 15 in the Fergus-Petroleum, 23 in the Powder River-Carter, and 24 in the Musselshell study areas. We did not capture in the Madison study area, which is a separate study that began in 2019 and that is being finalized; however, we include the Madison in this reporting given the information collected is identical and collars remain active.

In total, across all study areas from 2019 to 2022, we have captured and collared 702 animals. We outfitted each animal with a Lotek LiteTrack Iridium 420 collar programmed to collect locations every hour for 3 years, transmit a VHF signal during daylight periods, and transmit a mortality alert and signal if the device is stationary for ≥5 hours. These collars upload locations via Iridium satellites to a web platform for viewing and downloading near-real-time data. To date, across all study areas and years, a total of 45 (6% of total) collars have malfunctioned, 263 (38%) collared animals have died, and 394 (56%) collars remain active and will continue to be monitored until February 2023.

1.2 Survival monitoring and analysis

To date, 263 (38%) of the 702 collared animals have died, ranging 21 – 43 (32 – 45%) animals in each study area, and 45 (6%) collars have malfunctioned, ranging 2 – 13 (3 – 17%) collars in each study area (Figure 2). Mortality investigations were completed as soon as possible after receiving the mortality alerts. Across winters 2020, 2021, and 2022, mortalities associated with capture operations (capture myopathy or injury) totaled 33, ranging 1 – 9 mortalities in each study area (Figure 3). The remaining mortalities were classified as unknown (n = 70), predation (n = 66), natural (n = 39), legal harvest (n = 24), disease (n = 15), human-related (n = 7), and illegal take (n = 4). We classified mortalities as natural when evidence suggested the cause was due to injury, starvation, old age, or birth complications and when a carcass was found intact with no evidence of predation. A total of 394 collared animals are currently being monitored.

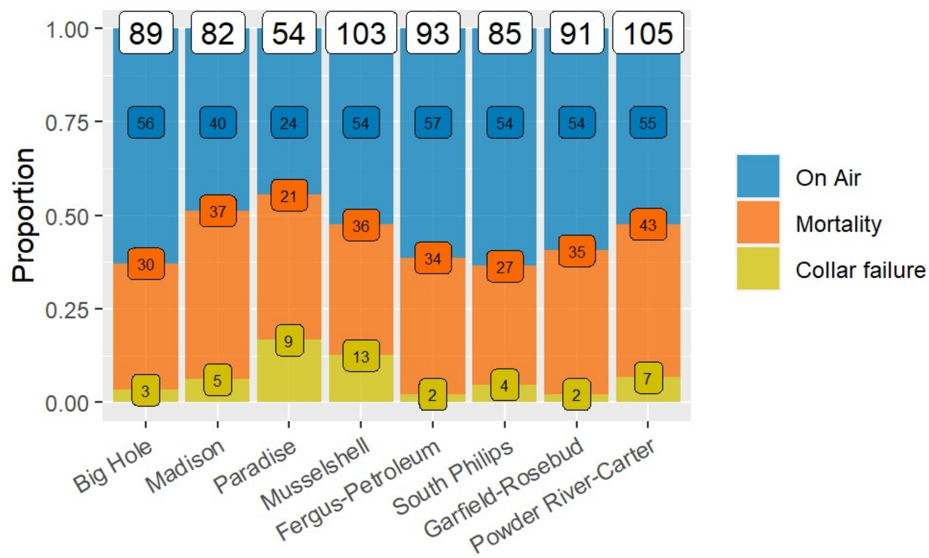


Figure 2. Number and proportion of total collared adult female pronghorn remaining on air, dead, or with a malfunctioned collar in each study area across 2019 – 2022 in the Montana Pronghorn Movement and Population Ecology Project as of June 30, 2022. The total number of collared animals in each study area is labeled at the top of each bar.

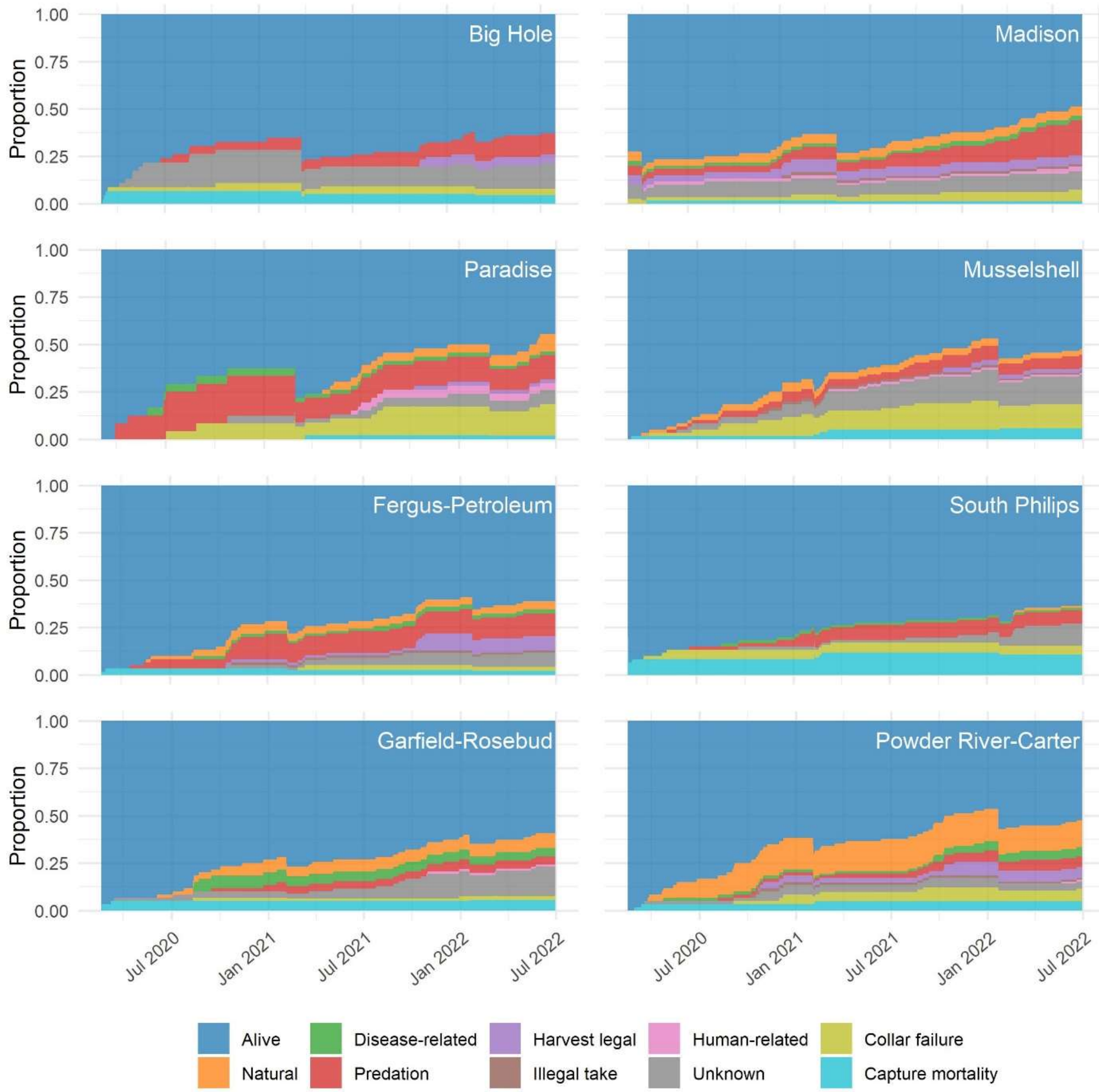


Figure 3. Proportion of the total adult female pronghorn collared across 2020 – 2022 remaining alive, dead, or with a malfunctioned collar in each study area in the Montana Pronghorn Movement and Population Ecology Project through June 30, 2022. Cause of death was determined by field investigations.

Based on known fate information from the collared pronghorn, we estimated monthly and annual survival by population for 2 biological years spanning 01 Jun – 31 May (i.e., 2020 – 2021 and 2021 – 2022). To do so, we used a multi-state survival model with known detection (in this case, perfect detection is assumed) in a Bayesian framework. Multi-state survival models are flexible to a range of recapture period lengths (occasion lengths) and can integrate the influence of individual animal states and transition between states on survival rates. We built the model using an encounter history of length = 24 (24 months across two years) which includes two animal-years. In our analysis, we censored mortalities that occurred within 14 days of capture and estimated baseline-survival rate, which includes harvest-related mortality and illegal take (Brodie et al. 2013). The estimated survival is the probability that an animal alive at the start of one occasion (i.e., a month) will survive to the start of the next occasion (the next month). From these data, we used the survival model to first estimate mean monthly survival and then estimate annual survival by taking the product of all months' survival probabilities within each population.

Monthly survival probabilities across study populations varied between 0.87 (95% credible interval [CRI] 0.73 – 0.96) and 0.97 (CRI 0.92 – 1.00), with the lowest occurring in Jul 2020 and the highest occurring in Feb 2022 (Figure 4). The lowest monthly survival estimates occurred in Mar 2020 in Paradise (0.78, CRI 0.39 – 0.97), Nov 2020 in Powder River-Carter (0.88, CRI 0.78 – 0.95), and in Nov 2021 in Fergus Petroleum (0.88, CRI 0.79 – 0.94). The highest monthly survival estimates occurred in Feb 2022 in Fergus-Petroleum (0.97, CRI 0.92 – 1.00) and Powder River-Carter (0.97, CRI 0.92 – 1.00).

Annual survival estimates within populations demonstrated slight increases in point estimates from 2021 to 2022 in most populations (excluding Madison) and ranged from a low of 0.66 (CRI 0.54 - 0.77) in 2021 for Powder River-Carter to a high of 0.83 (CRI 0.73 - 0.92) in 2021 for Madison (Figure 5; Table 1). However, credible intervals overlapped across years within populations and across all populations, suggesting that there was no difference in annual survival between years for each population nor across populations. The survival estimates reported here include 22 harvested individuals from 6 of the 8 populations: Big Hole, Fergus-Petroleum, Madison, Musselshell, Paradise, and Powder River-Carter (Table 2). Most of the pronghorn (17 of 22) were harvested in 2021 with the majority from the Fergus-Petroleum (n = 7) and Powder River-Carter herds (n = 6).

The next steps for these analyses include adding spatial and temporal covariates (drought severity, winter conditions, road, and fence densities, etc.) to gain further insight into how landscape and climatic factors influence pronghorn survival rates across populations.

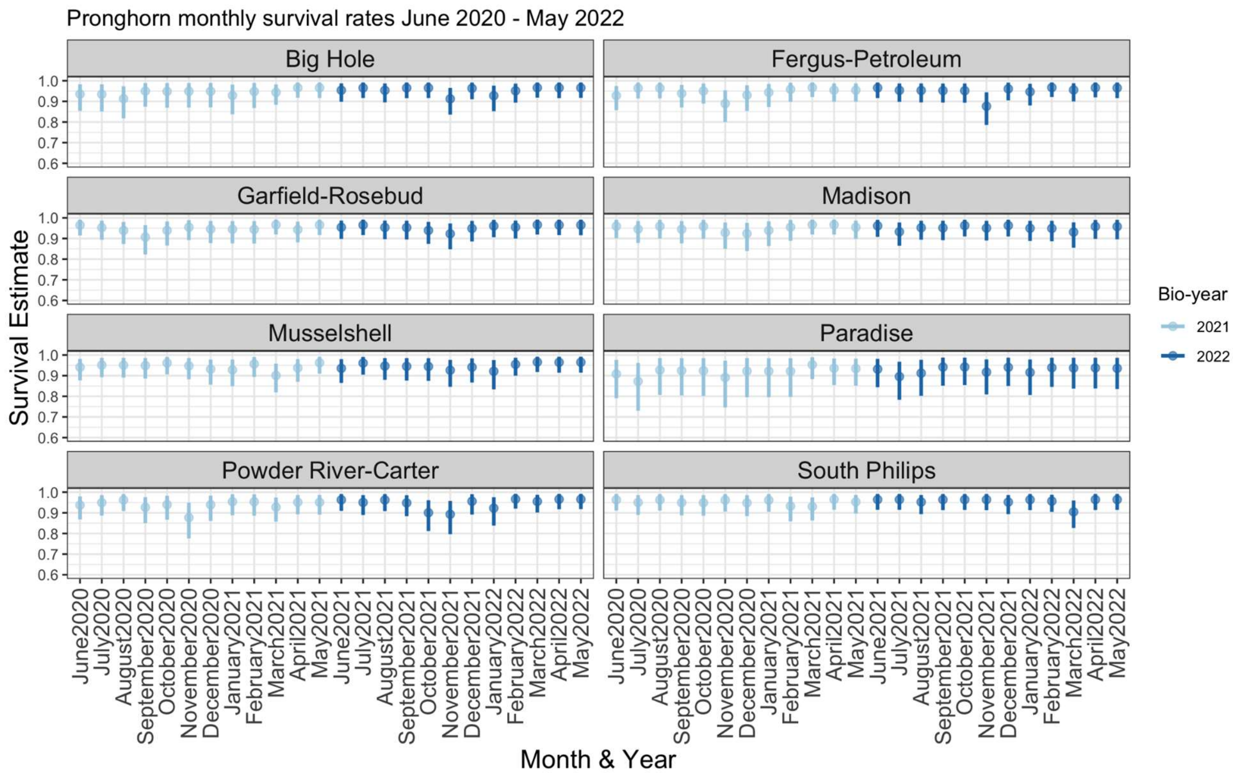


Figure 4. Mean monthly survival probabilities (and 95% credible intervals) for each study population and biological year (2021 = 01 Jun 2020 – 31 May 2021; 2022 = 01 Jun 2021 – 31 May 2022) estimated from known fate information of collared adult female pronghorn in the Montana Pronghorn Movement and Population Ecology Project. The estimated probabilities represent the probability that an animal alive in one month will survive to the next month.

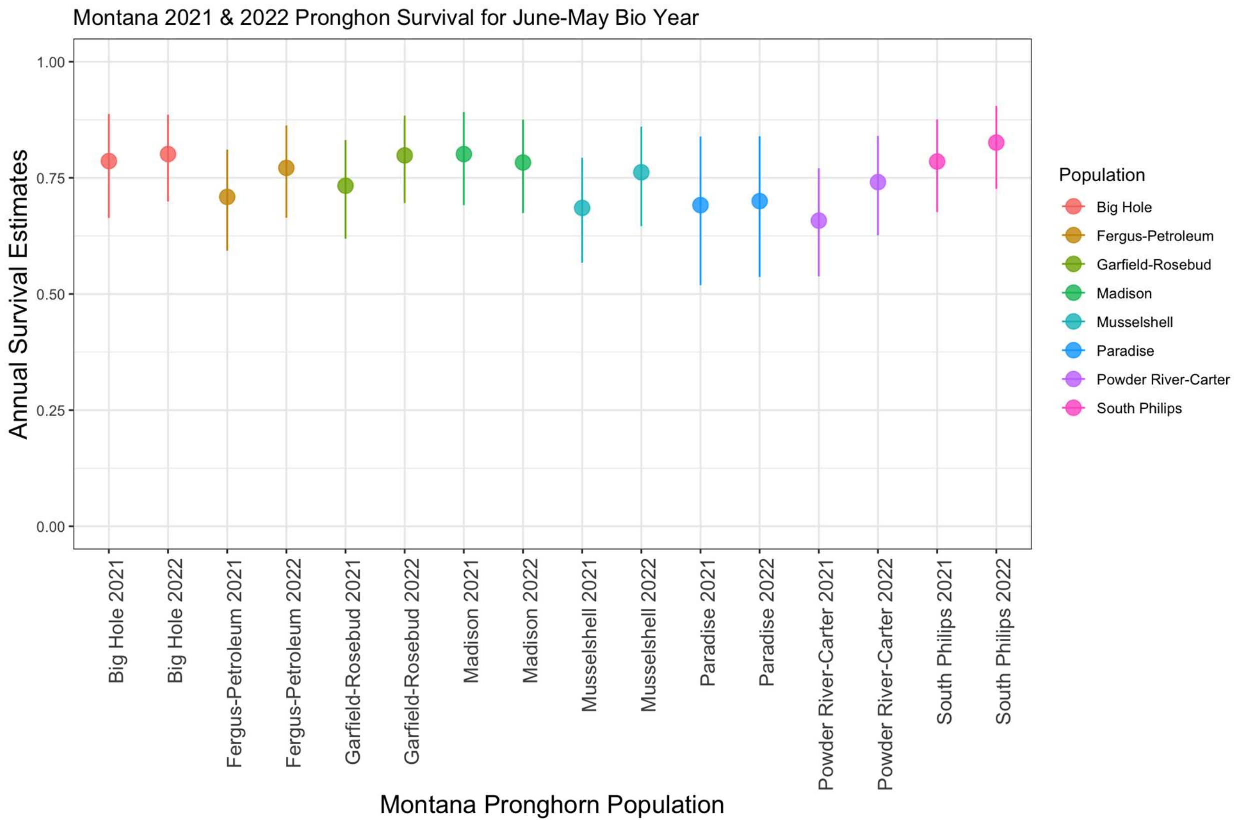


Figure 5. Annual survival probabilities (and 95% credible intervals) estimated from known fate information of collared adult female pronghorn for each study populations and biological year (2021 = 01 Jun 2020 – 31 May 2021; 2022 = 01 Jun 2021 – 31 May 2022) in the Montana Pronghorn Movement and Population Ecology Project. The estimated probabilities are the product of each respective biological years' 12 months of survival probabilities for each study population.

Table 1. Annual survival probabilities and 95% credible intervals estimated from known fate information of collared adult female pronghorn for each study population and for all study populations (the "Total Annual Survival" row) for each biological year (2021 = 01 June 2020 – 31 May 2021; 2022 = 01 June 2021 – 31 May 2022). The estimated probabilities are the product of each respective biological years' 12 months of survival probabilities for each study population.

Study area	n	Year	Annual survival	95% credible interval 2.5%	97.5%
Big Hole	61	2021	0.78	0.66	0.89
	61	2022	0.80	0.70	0.88
Madison	60	2021	0.83	0.73	0.92
	50	2022	0.78	0.67	0.87
Paradise	36	2021	0.69	0.51	0.84
	23	2022	0.70	0.54	0.84
Musselshell	60	2021	0.68	0.57	0.79
	60	2022	0.76	0.65	0.86
Fergus-Petroleum	61	2021	0.71	0.59	0.81
	61	2022	0.77	0.66	0.86
South Philips	62	2021	0.79	0.68	0.88
	62	2022	0.82	0.72	0.91
Garfield-Rosebud	61	2021	0.73	0.62	0.83
	60	2022	0.80	0.70	0.88
Powder River-Carter	58	2021	0.66	0.53	0.77
	60	2022	0.74	0.63	0.84

Table 3. Legally harvested collared pronghorn from 6 of the 8 herds in the Montana Pronghorn Movement and Population Ecology Project. Harvest data include October 2020 and October 2021 harvests with the majority of collared pronghorn harvested in 2021.

Herd	Animal ID	Mortality Date
Big Hole	BH2001	2021-10-09
	BH2106	2021-10-09
	BH2125	2021-10-10
	BH2113	2021-10-22
Fergus-Petroleum	FE2051	2020-10-14
	FE2048	2021-10-09
	FE2111	2021-10-09
	FE2033	2021-10-10
	FE2115	2021-10-14
	FE2037	2021-10-21
	FE2103	2021-10-27
Madison	MA1935	2020-10-14
	MA2007	2020-11-08
Musselshell	MU2027	2021-10-09
	MU2113	2021-10-09
Paradise	PA2105	2021-10-09
Powder River-Carter	AL2026	2020-10-21
	AL2023	2020-10-30
	AL2116	2021-10-09
	AL2048	2021-10-10
	AL2025	2021-10-11
	AL2104	2021-10-29

1.3 Seasonal ranges and migration corridors

To date, we have collected 8,055,574 locations from 702 individuals, averaging 11,726 (range: 7 – 29,966) locations per individual. Movement patterns of individuals were diverse within and across study areas (Figure 6 – 29), with individuals that demonstrate non-migratory behaviors comprising the majority (65 – 95%) of individuals in each study area except the Big Hole, and with migratory behaviors most prevalent (20 – 35% of the individuals) in the Big Hole, Madison, and South Philips study areas relative to the other study areas (see Section 1.4 for a description of the characterization methods and summaries of migratory behaviors). Here, we present maps of each study area's individual movement trajectories and estimated population-level migration corridors and seasonal ranges delineated from the collar location data collected to date. Estimates of migration corridors and seasonal ranges shown in this report are preliminary and will be finalized at the end of location data collection. Of note in one instance in the Big Hole, a collar from an animal captured in winter 2020 that failed September 2020 was recovered spring 2022 from a private landowner in the Lemhi valley, Idaho, indicating that an unmapped migratory route may exist between Montana and Idaho over Lemhi Pass (Figure 6).

To estimate migration corridors (Figure 7 – 28), we identified migration periods for each individual-year (see Section 1.4) and used Brownian Bridge Movement Model (BBMM; Horne et al. 2007) methods to delineate population-level migration routes. The BBMM estimates the probability of where an animal could have traveled between two sequential GPS locations. When this process is applied to all GPS locations in a migration sequence, the BBMM provides a utilization distribution (UD) estimate of the width of the estimated movement path around the straight line between the successive locations and can be used to estimate migration routes (Sawyer et al. 2009) and stopover sites (Sawyer and Kauffman 2011). Because we were interested in classifying migration strategies and migratory periods for full "migratory years," which we defined to span 01 Feb – Jan 31 (see Section 1.4), individuals with movement data occurring after 01 Feb 2022 were incomplete and not included in this analysis this year. In general, we applied a four-step process to calculate population-level migration routes which generally followed the approach outlined by Sawyer et al. (2009). We first estimated unique UDs for each migration sequence using a grid with 50-m resolution. Second, 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 then rescaled this averaged UD to sum to 1. Third, we defined a migration route footprint for each individual as the 99% isopleth of the UD. Lastly, we stacked all the individual footprints for a given study area and converted the migration routes from a grid-based format to a polygon format, while removing isolated use polygons of less than 20,000 m^2 (i.e., less than approximately 5 acres). When converting final migration route from grid to polygon data, all 50-m pixels were preserved in the final migration routes. Thus, the mapped migration routes represent areas used by ≥1 migrant during spring and/or fall migration periods.

To calculate seasonal ranges (Figure 8 – 29), we randomly sampled 4 locations per day per individual and estimated a 95% kernel utilization distribution (KUD) for each season and study area (i.e., population-level). The 95% KUD represents the area in which the probability of relocating an animal is equal to 0.95. We defined spring as April 1 – June 30, summer as July 1 – Aug 31, fall as September 1 – November 30, and winter as December 1 – March 31.

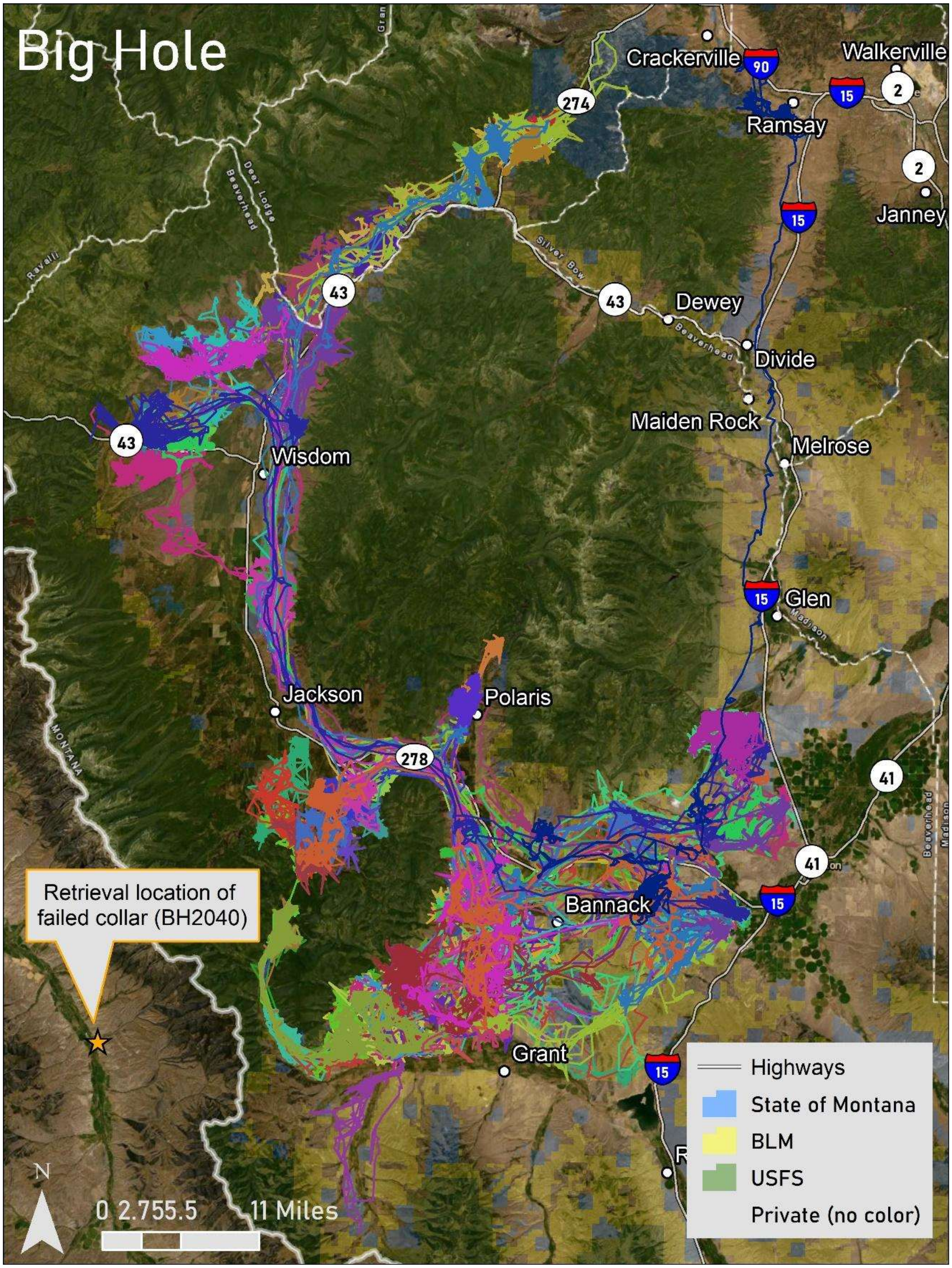


Figure 6. Movements of collared adult female pronghorn (colored by individual) in the Big Hole study area for the Montana Pronghorn Movement and Population Ecology Project, as of June 30, 2022. See the text for a description related to the location of the failed collar in Idaho.

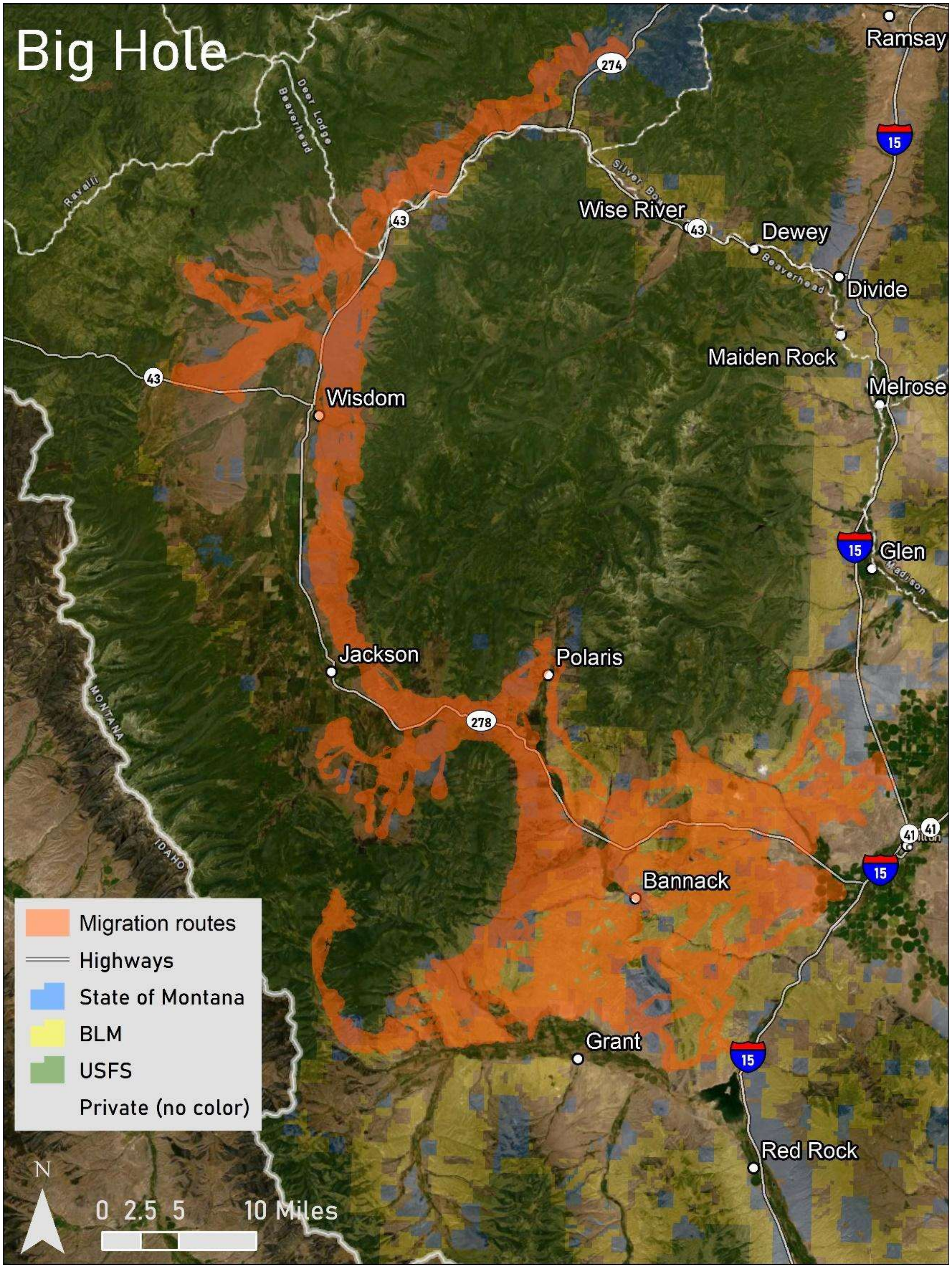


Figure 7. Preliminary estimates of migration routes of migrant collared adult female pronghorn in the Big Hole study area for the Montana Pronghorn Movement and Population Ecology Project. Migration routes represent areas used by ≥1 migrant during spring and/or fall migration periods. Individuals with movement data occurring after 01 Feb 2022 are not displayed.

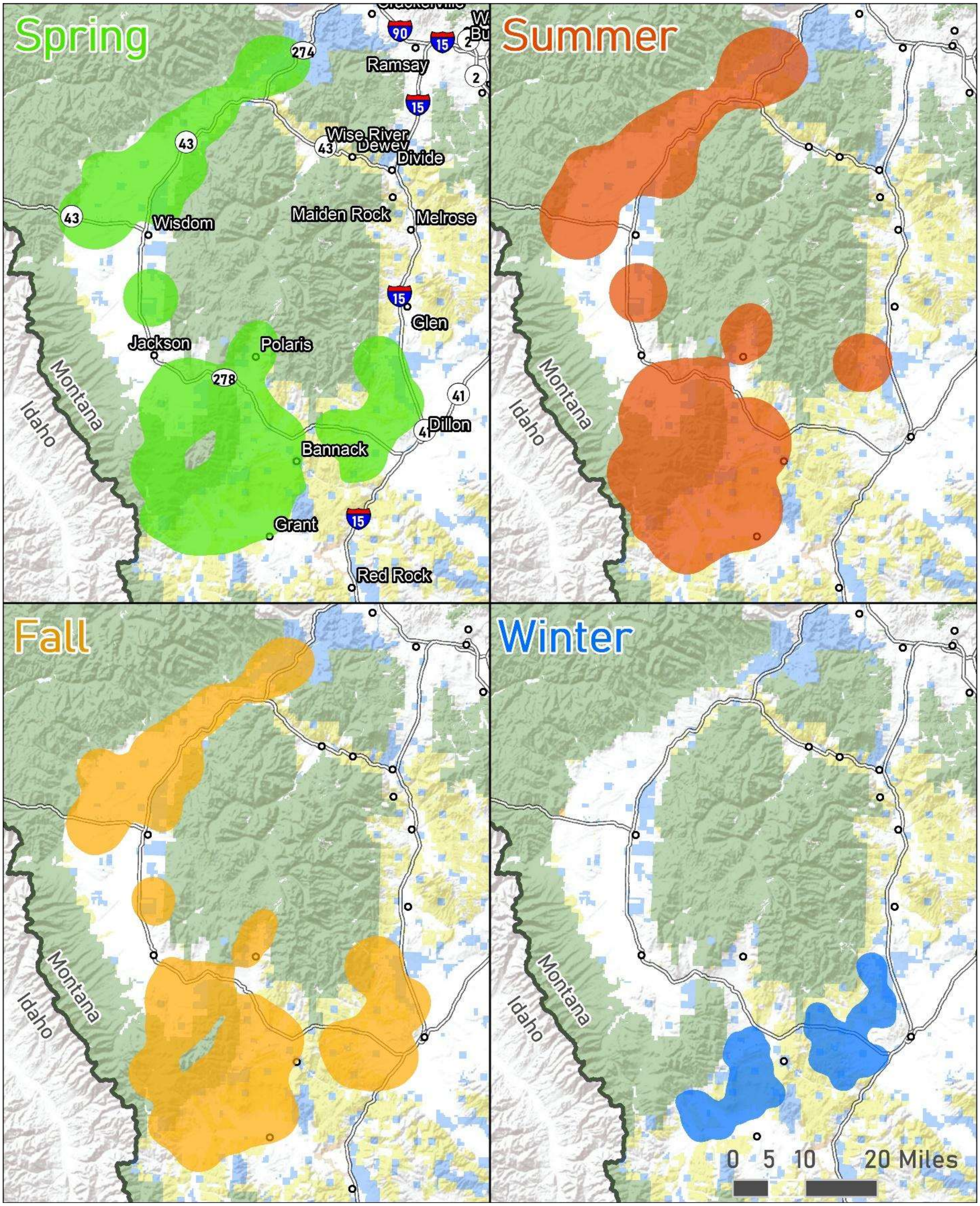


Figure 8. Seasonal ranges of collared adult female pronghorn in the Big Hole study area for the Montana Pronghorn Movement and Population Ecology Project, as of June 30, 2022. Spring: Apr 1 – Jun 30; Summer: Jul 1 – Aug 31; Fall: Sep 1 – Nov 30; Winter: Dec 1 – Mar 31.

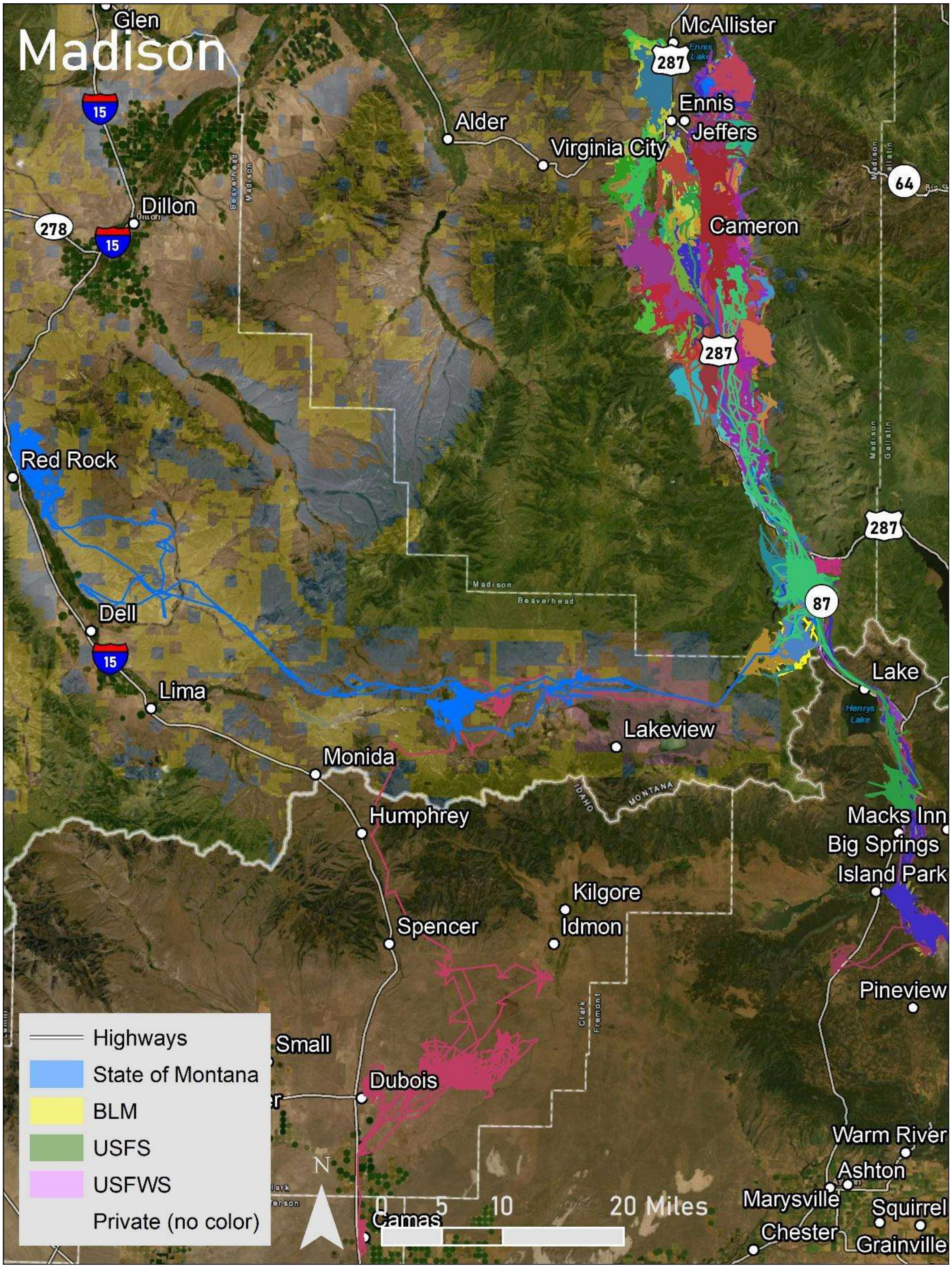


Figure 9. Movements of collared adult female pronghorn (colored by individual) in the Madison study area for the Montana Pronghorn Movement and Population Ecology Project as of June 30, 2022.

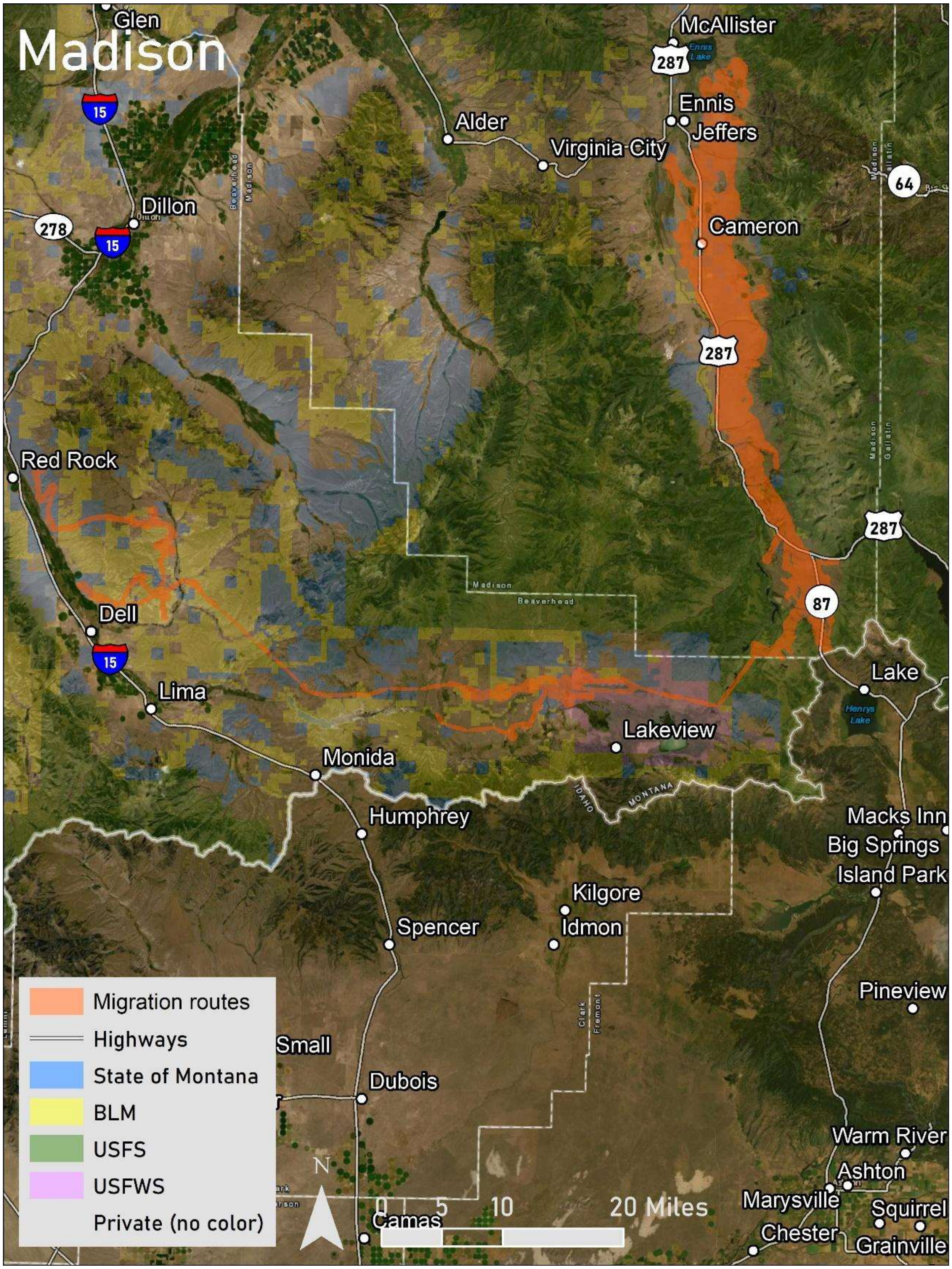


Figure 10. Preliminary estimates of migration routes of migrant collared adult female pronghorn in the Madison study area for the Montana Pronghorn Movement and Population Ecology Project. Migration routes represent areas used by ≥1 migrant during spring and/or fall migration periods and are clipped to Montana only. Individuals with movement data occurring after 01 Feb 2022 are not displayed.

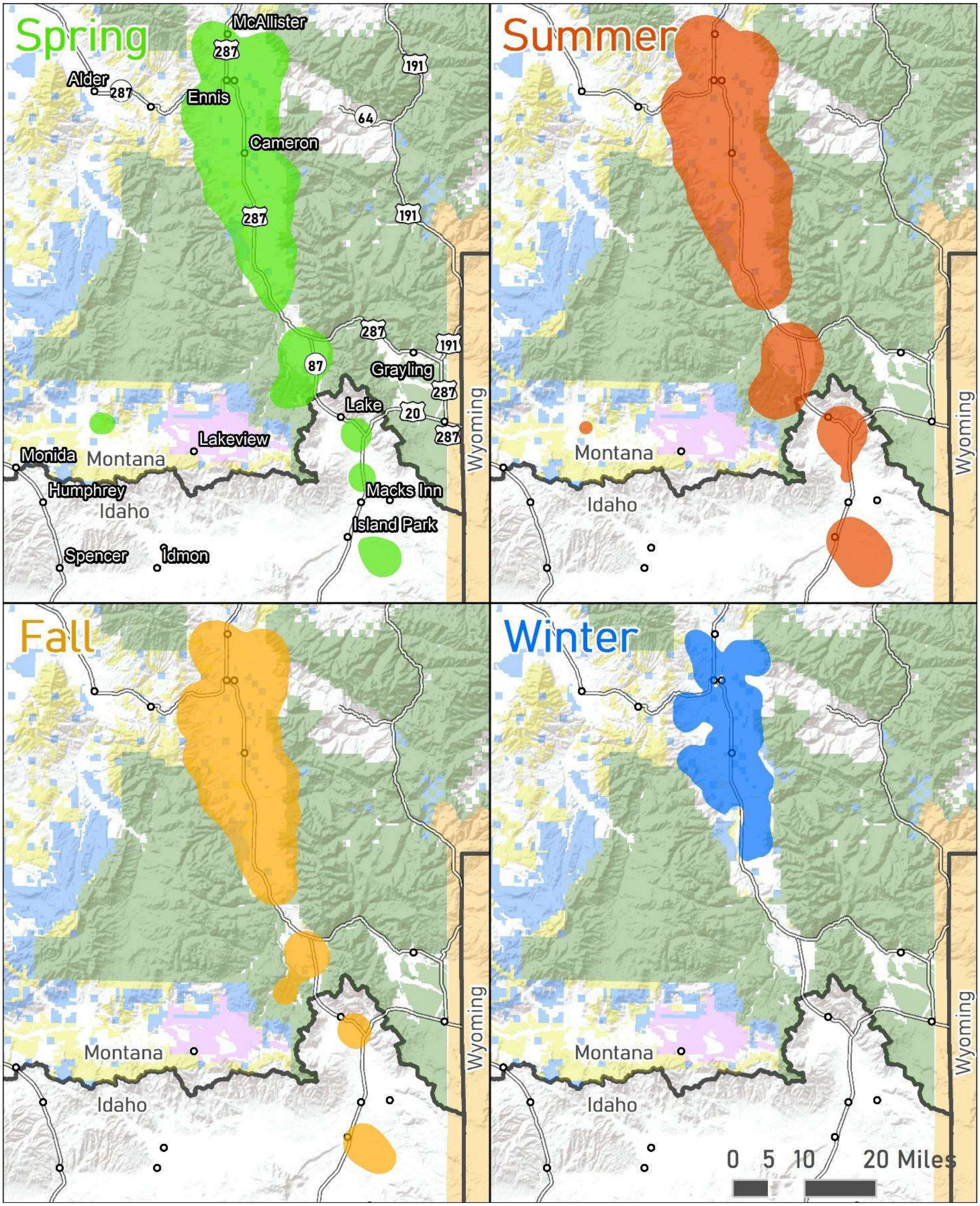


Figure 11. Seasonal ranges of collared adult female pronghorn in the Madison study area for the Montana Pronghorn Movement and Population Ecology Project, as of June 30, 2022. Spring: Apr 1 – Jun 30; Summer: Jul 1 – Aug 31; Fall: Sep 1 – Nov 30; Winter: Dec 1 – Mar 31.

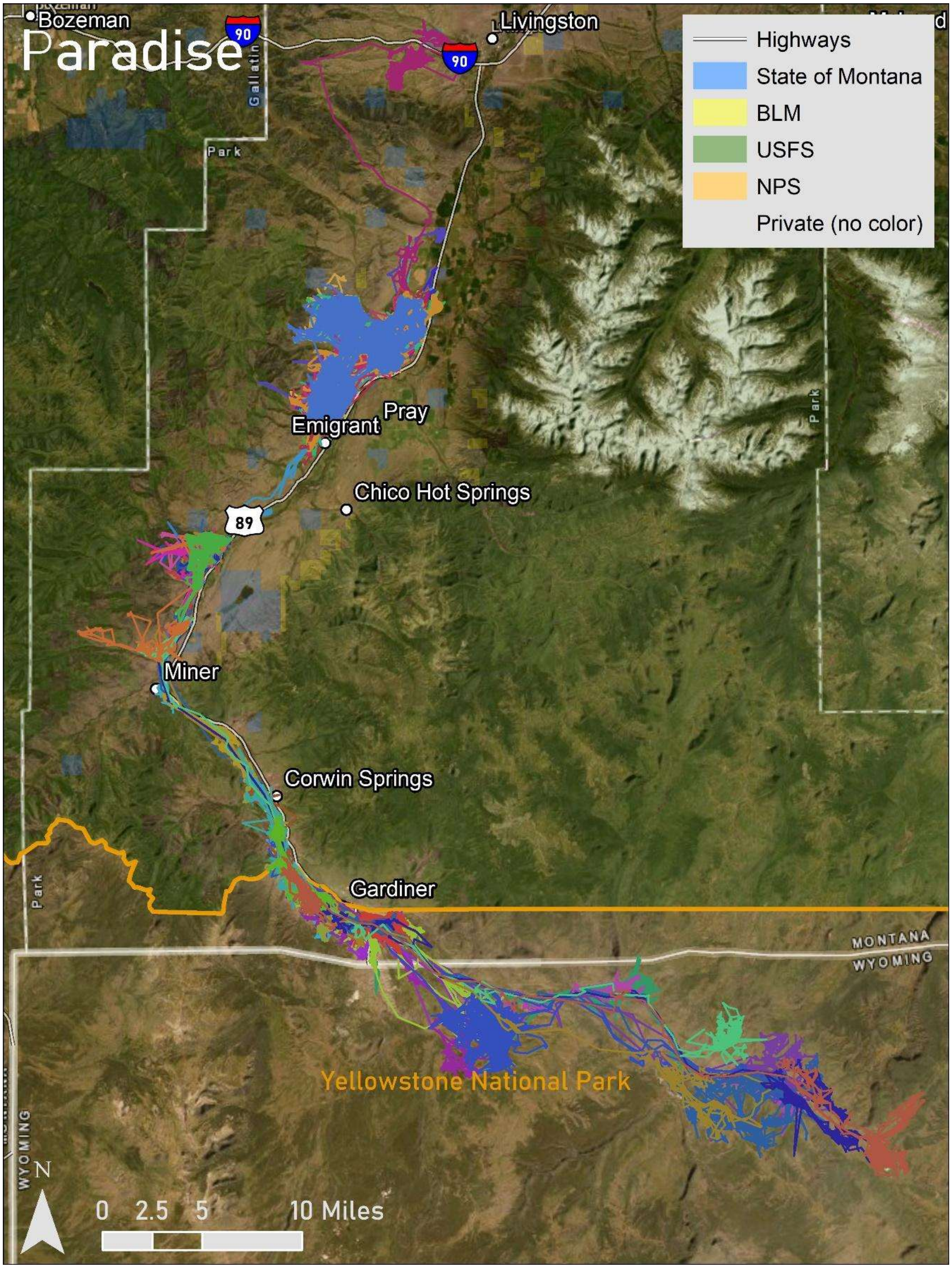


Figure 12. Movements of collared adult female pronghorn (colored by individual) in the Paradise study area for the Montana Pronghorn Movement and Population Ecology Project, as of June 30, 2022.

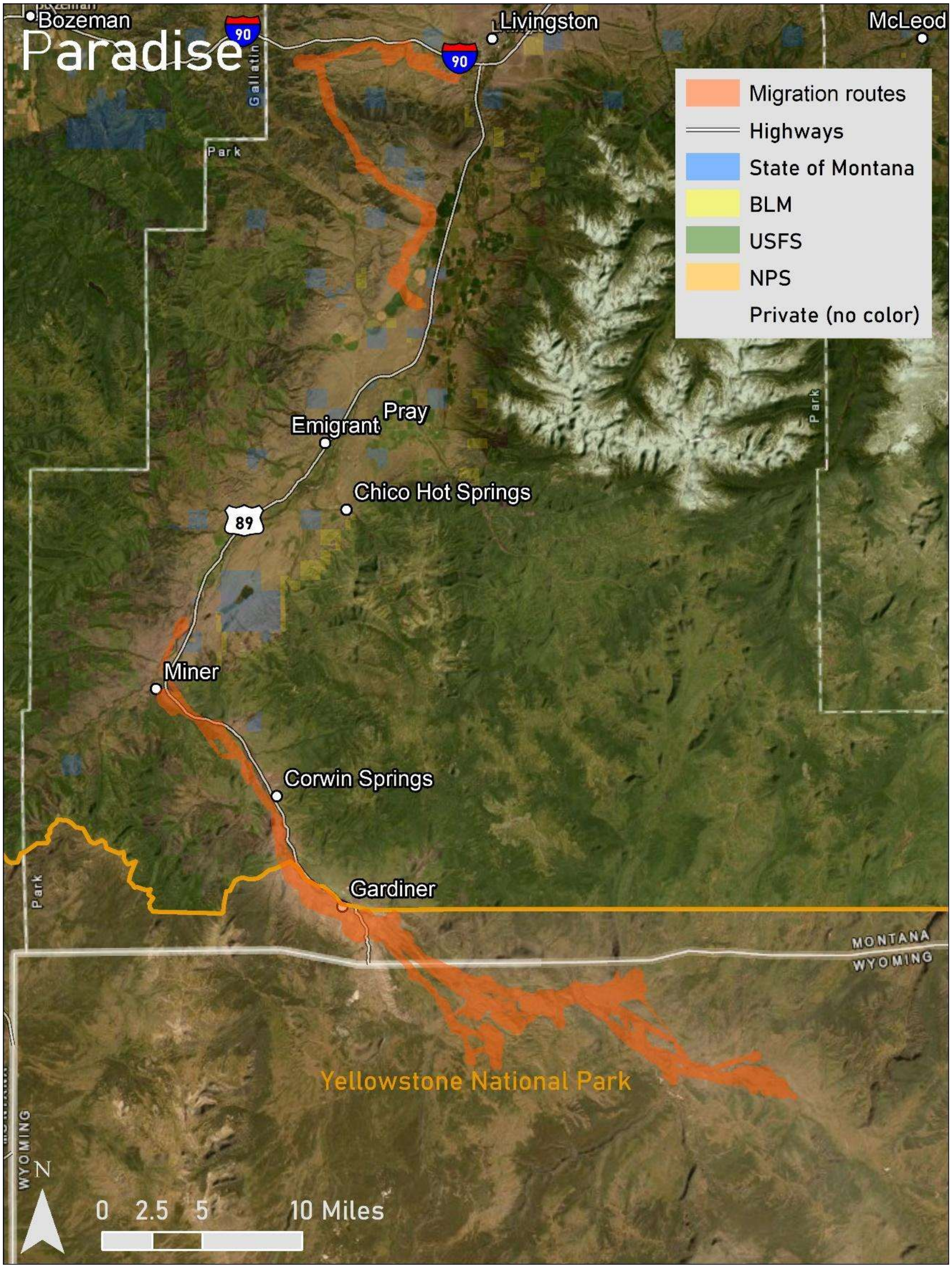


Figure 13. Preliminary estimates of migration routes of migrant collared adult female pronghorn in the Paradise study area for the Montana Pronghorn Movement and Population Ecology Project. Migration routes represent areas used by ≥1 migrant during spring and/or fall migration periods. Individuals with movement data occurring after 01 Feb 2022 are not displayed.

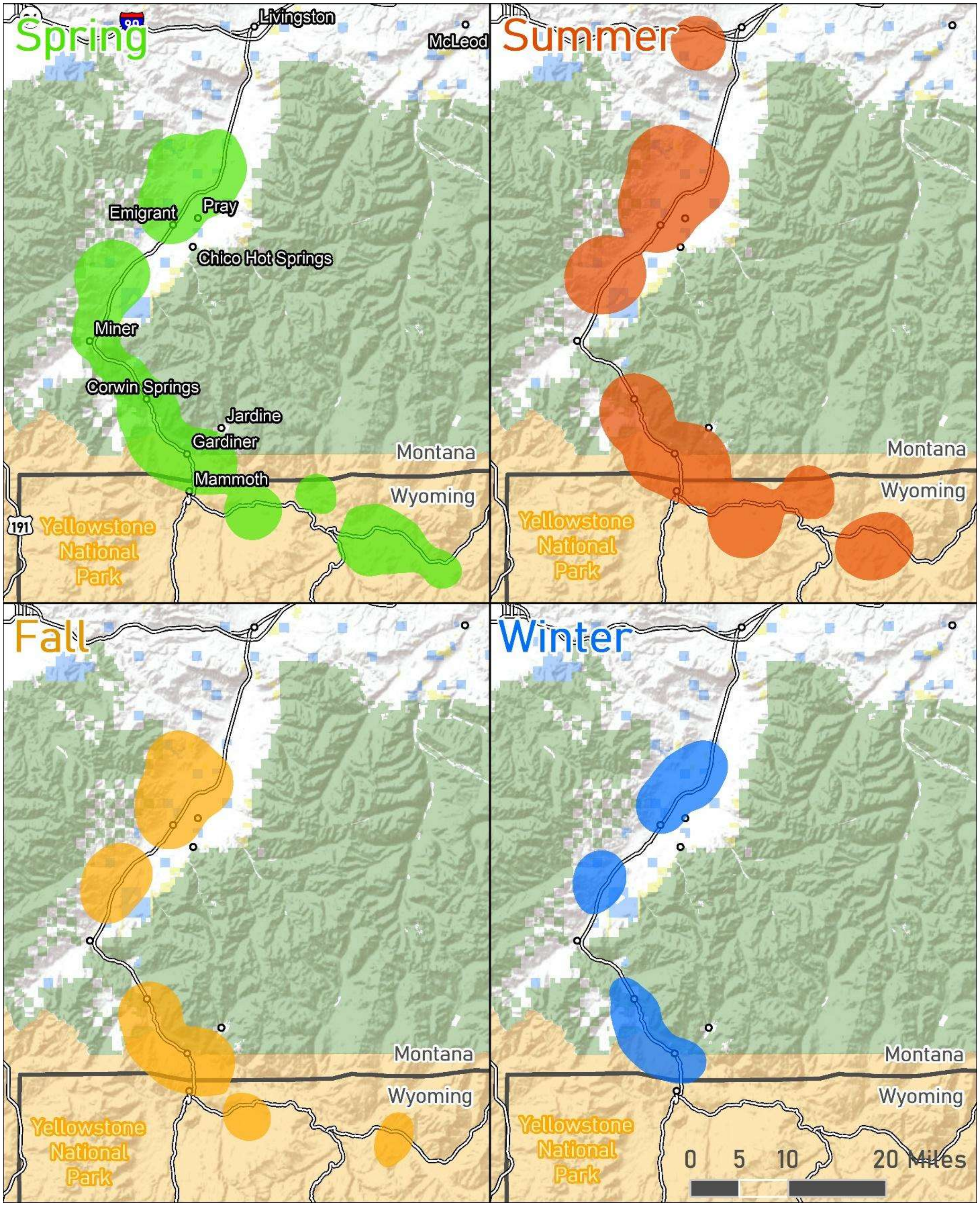


Figure 14. Seasonal ranges of collared adult female pronghorn in the Madison study area for the Montana Pronghorn Movement and Population Ecology Project, as of June 30, 2022. Spring: Apr 1 – Jun 30; Summer: Jul 1 – Aug 31; Fall: Sep 1 – Nov 30; Winter: Dec 1 – Mar 31.

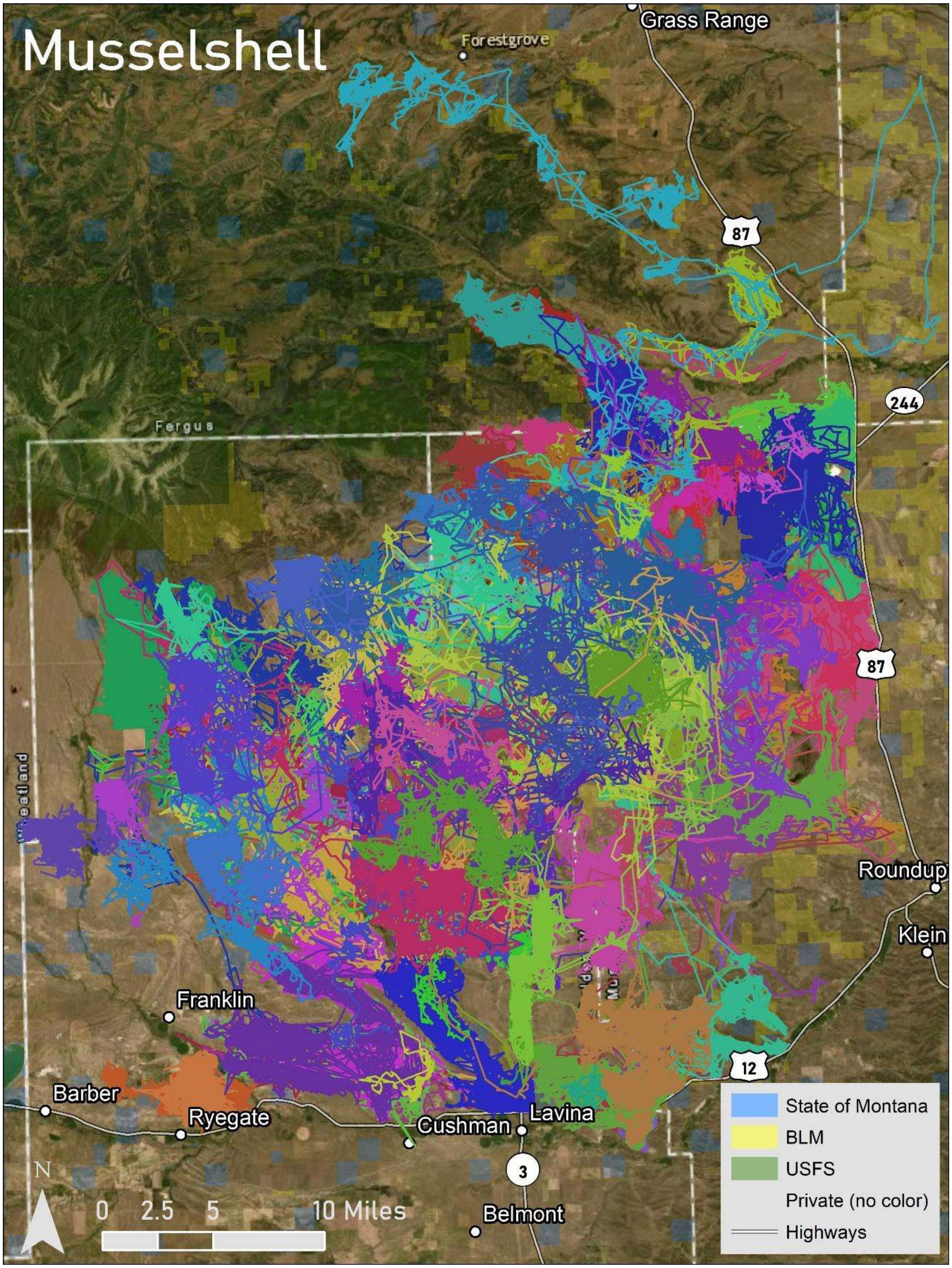


Figure 15. Movements of collared adult female pronghorn (colored by individual) in the Musselshell study area for the Montana Pronghorn Movement and Population Ecology Project, as of June 30, 2022.

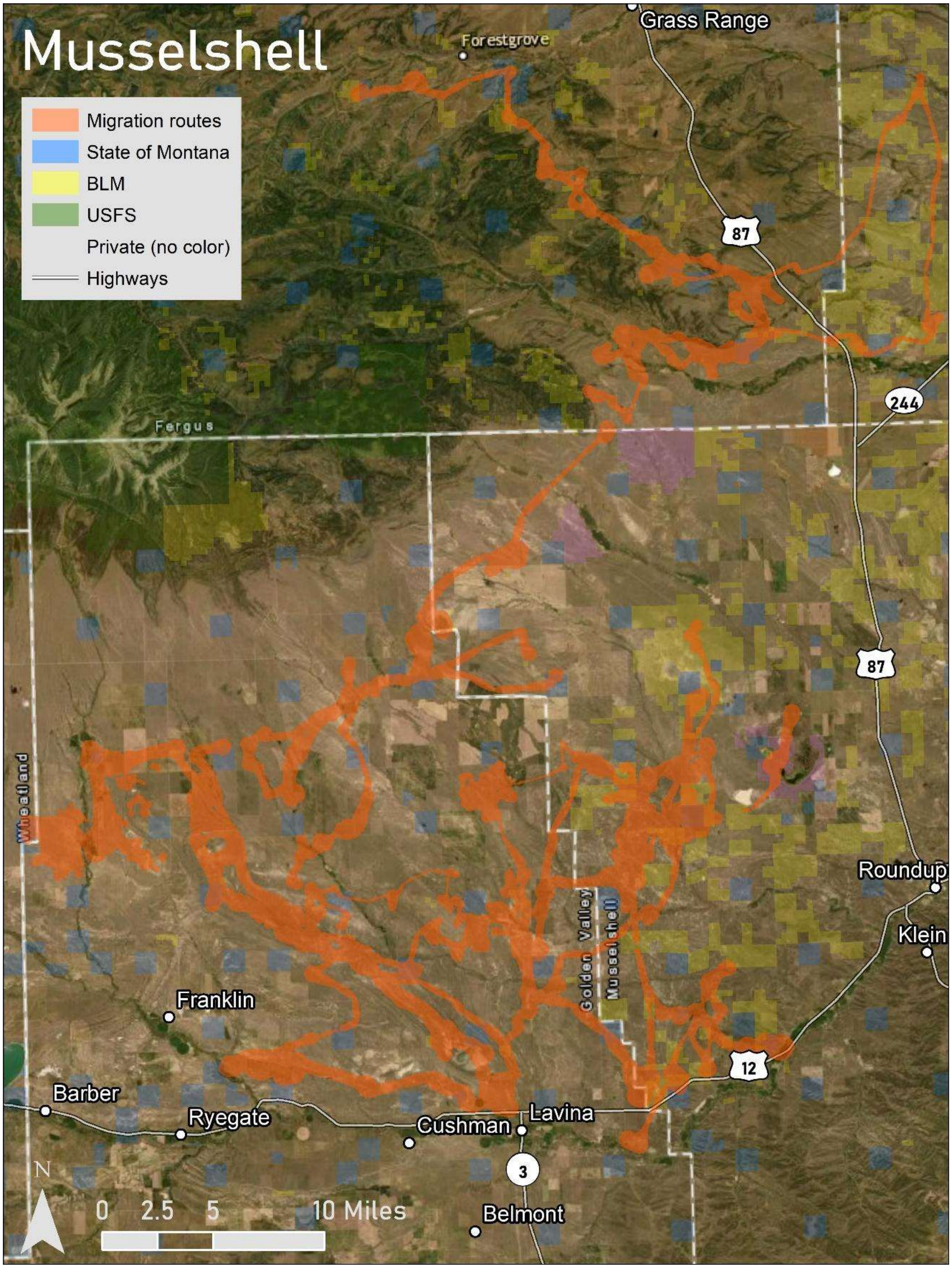


Figure 16. Preliminary estimates of migration routes of migrant collared adult female pronghorn in the Musselshell study area for the Montana Pronghorn Movement and Population Ecology Project. Migration routes represent areas used by ≥1 migrant during spring and/or fall migration periods. Individuals with movement data occurring after 01 Feb 2022 are not displayed.

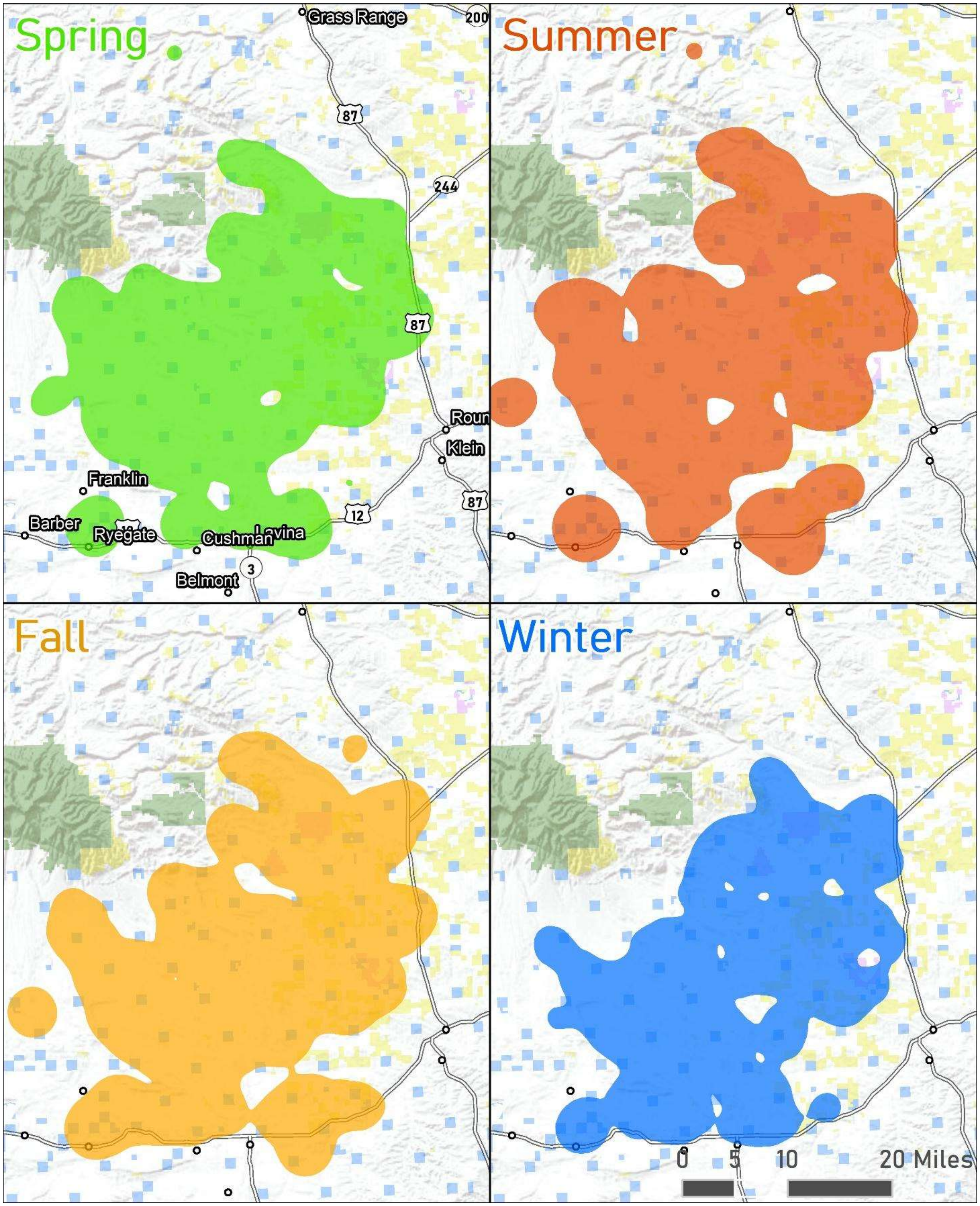


Figure 17. Seasonal ranges of collared adult female pronghorn in the Musselshell study area for the Montana Pronghorn Movement and Population Ecology Project, as of June 30, 2022. Spring: Apr 1 – Jun 30; Summer: Jul 1 – Aug 31; Fall: Sep 1 – Nov 30; Winter: Dec 1 – Mar 31.

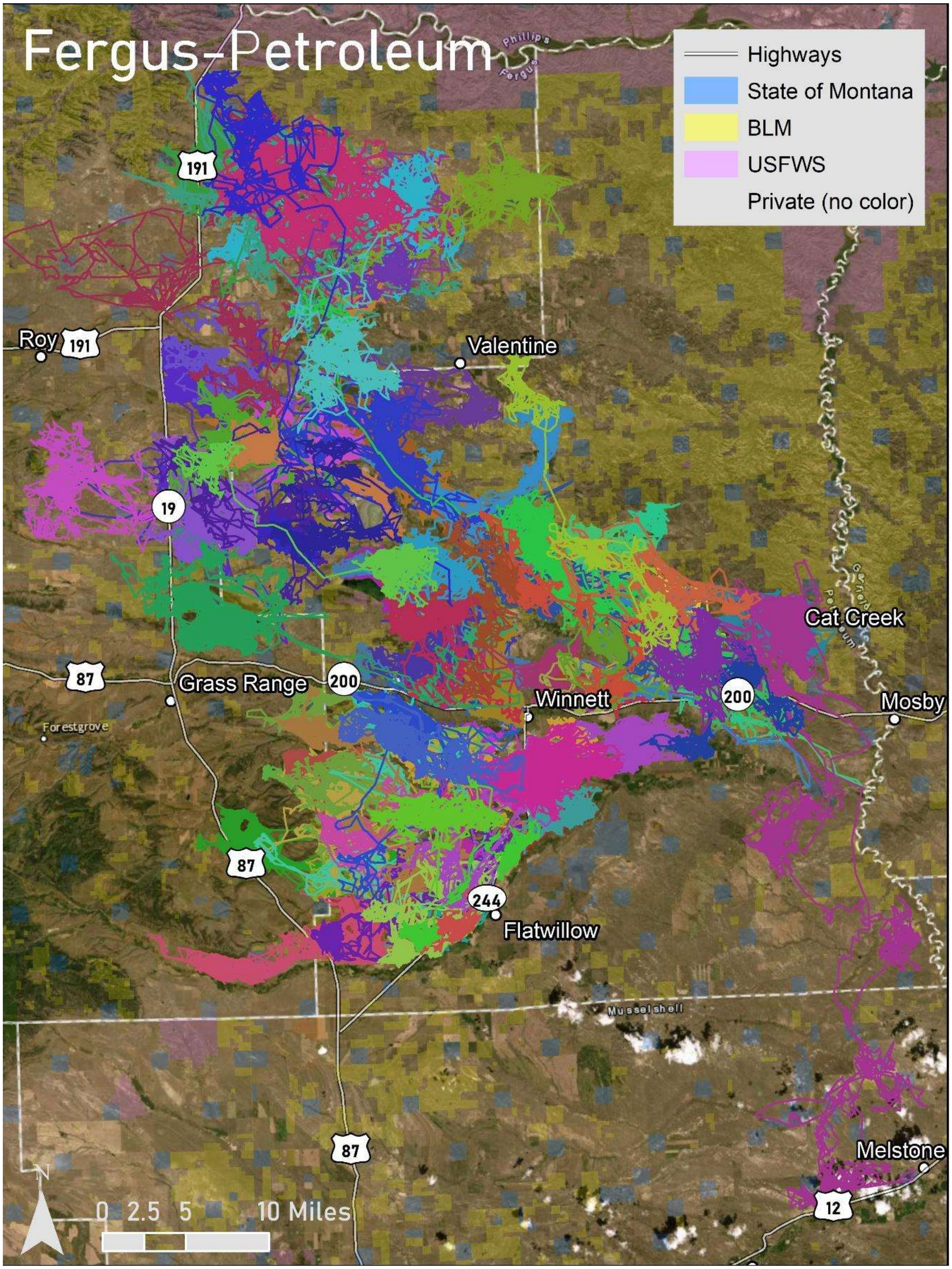


Figure 18. Movements of collared adult female pronghorn (colored by individual) in the Fergus-Petroleum study area for the Montana Pronghorn Movement and Population Ecology Project, as of June 30, 2022.

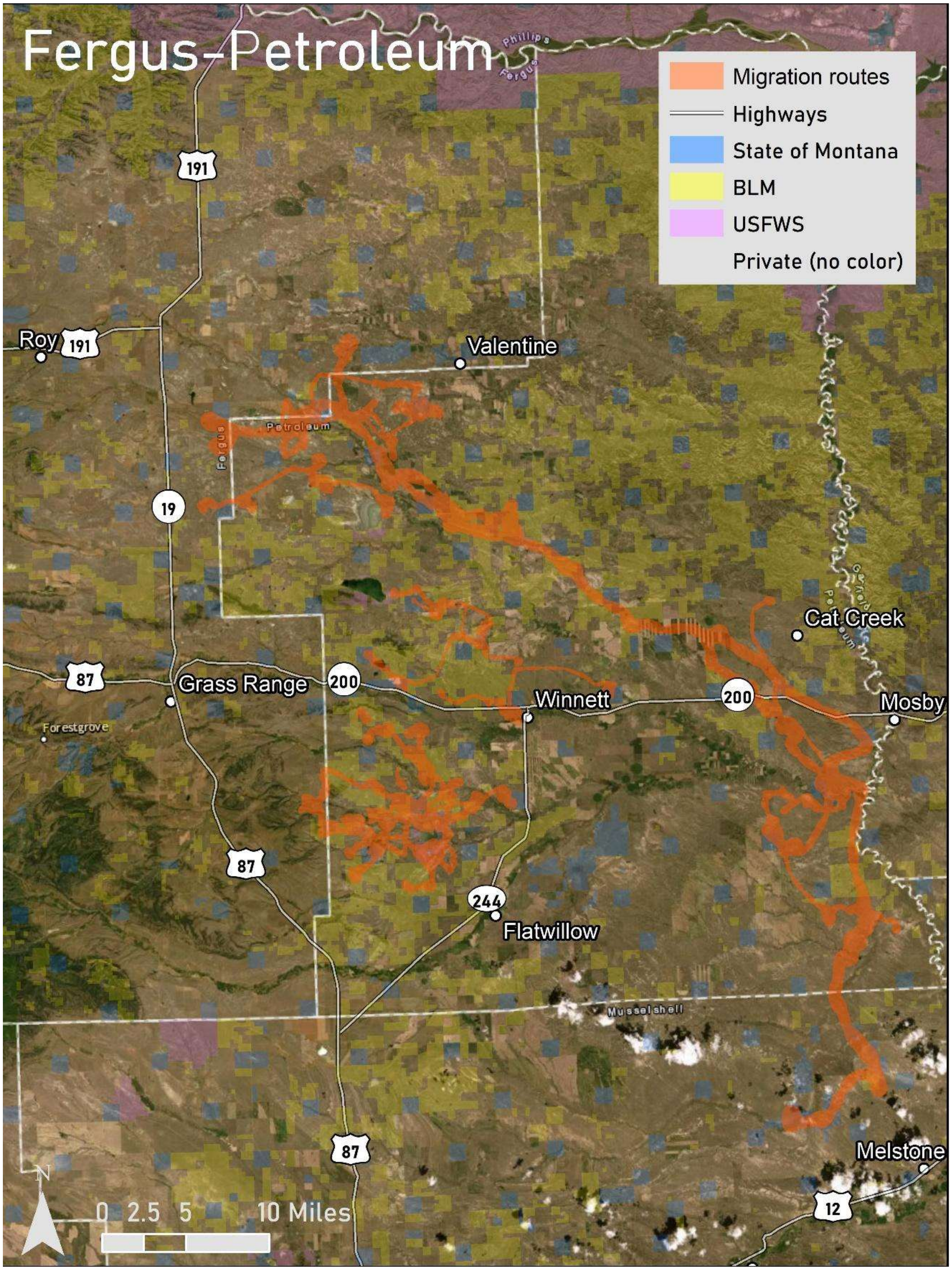


Figure 19. Preliminary estimates of migration routes of migrant collared adult female pronghorn in the Fergus-Petroleum study area for the Montana Pronghorn Movement and Population Ecology Project. Migration routes represent areas used by ≥1 migrant during spring and/or fall migration periods. Individuals with movement data occurring after 01 Feb 2022 are not displayed.

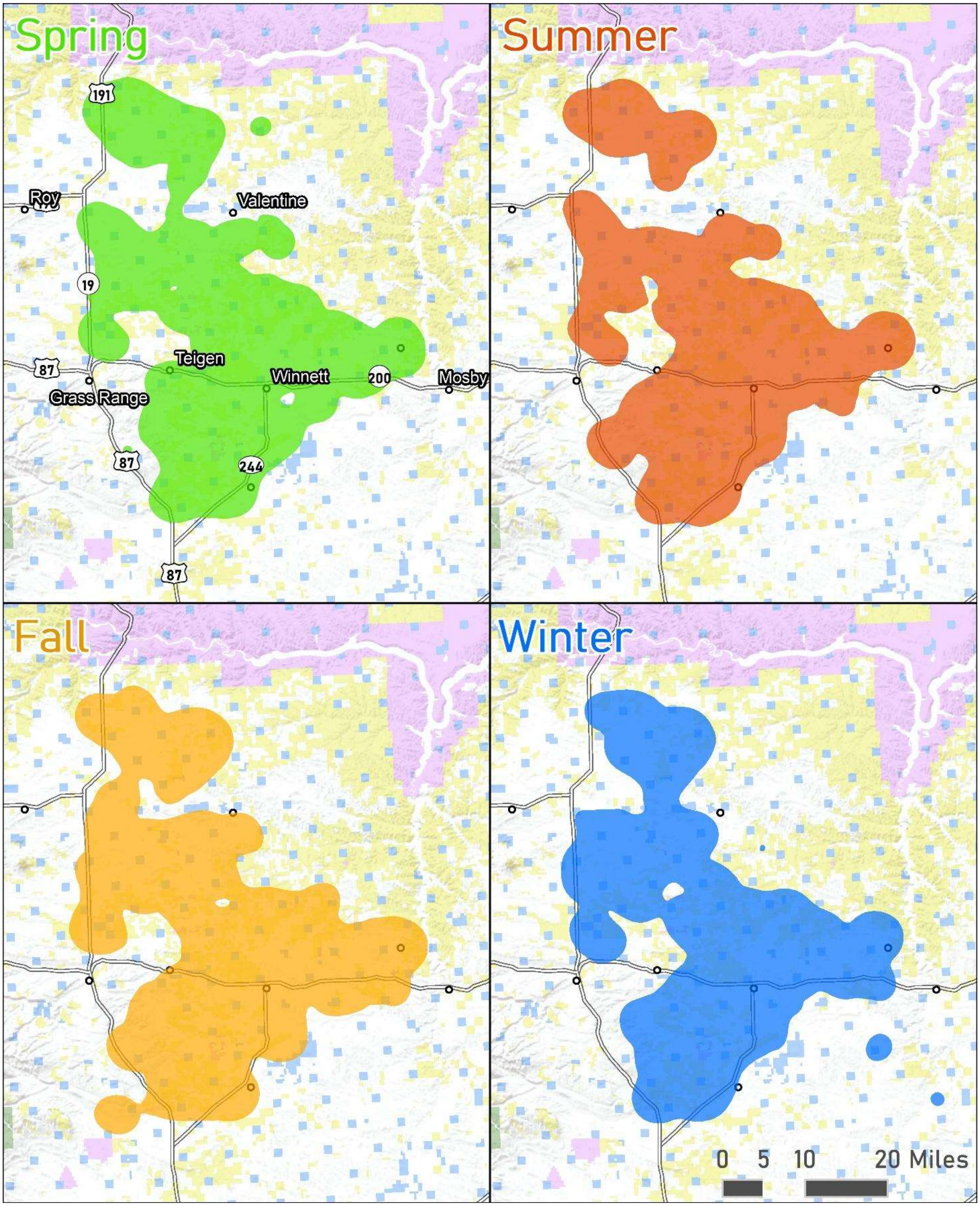


Figure 20. Seasonal ranges of collared adult female pronghorn in the Fergus-Petroleum area for the Montana Pronghorn Movement and Population Ecology Project, as of June 30, 2022. Spring: Apr 1 – Jun 30; Summer: Jul 1 – Aug 31; Fall: Sep 1 – Nov 30; Winter: Dec 1 – Mar 31.

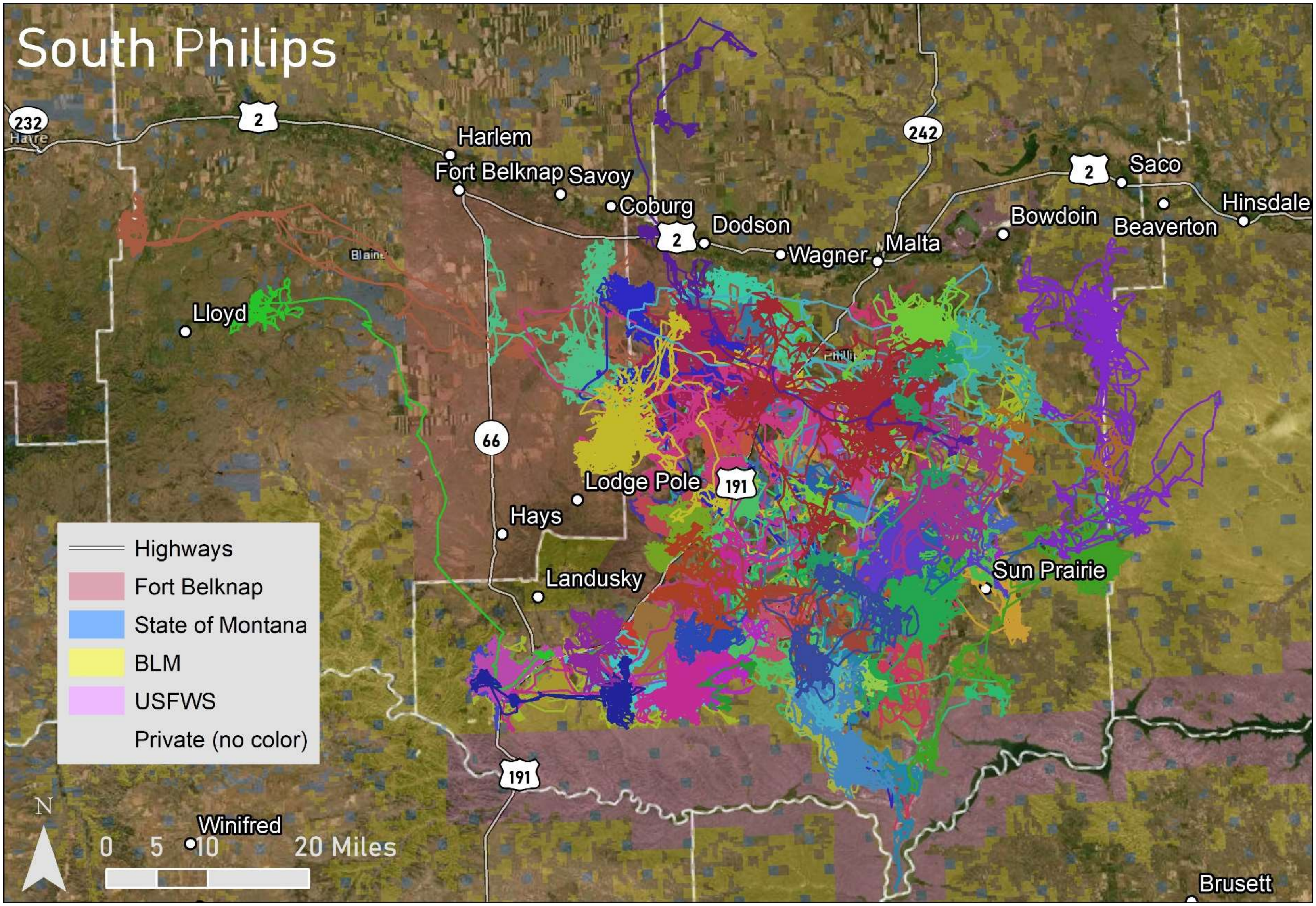


Figure 21. Movements of collared adult female pronghorn (colored by individual) in the South Philips study area for the Montana Pronghorn Movement and Population Ecology Project, as of June 30, 2022.

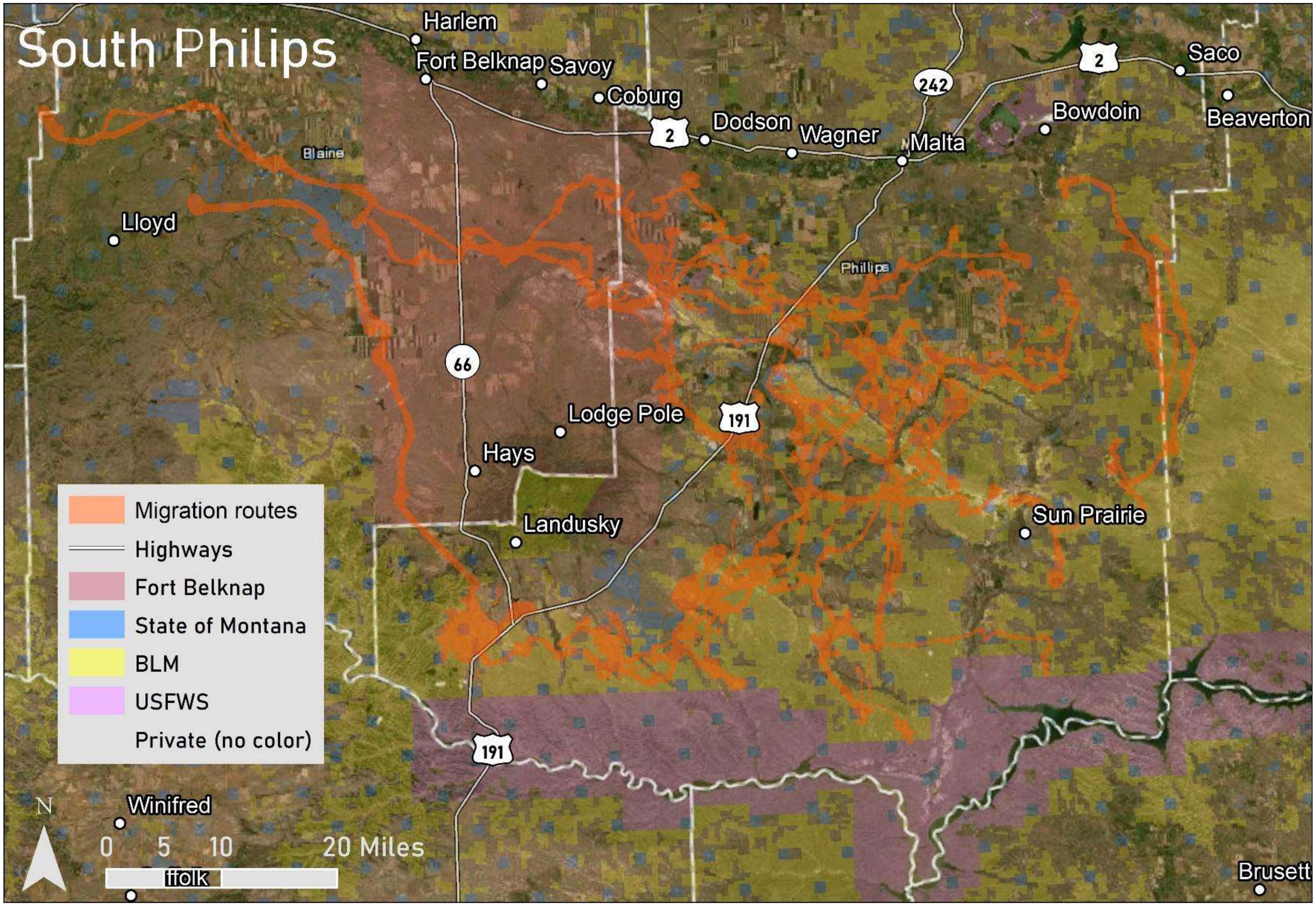


Figure 22. Preliminary estimates of migration routes of migrant collared adult female pronghorn in the South Philips study area for the Montana Pronghorn Movement and Population Ecology Project. Migration routes represent areas used by ≥1 migrant during spring and/or fall migration periods. Individuals with movement data occurring after 01 Feb 2022 are not displayed.

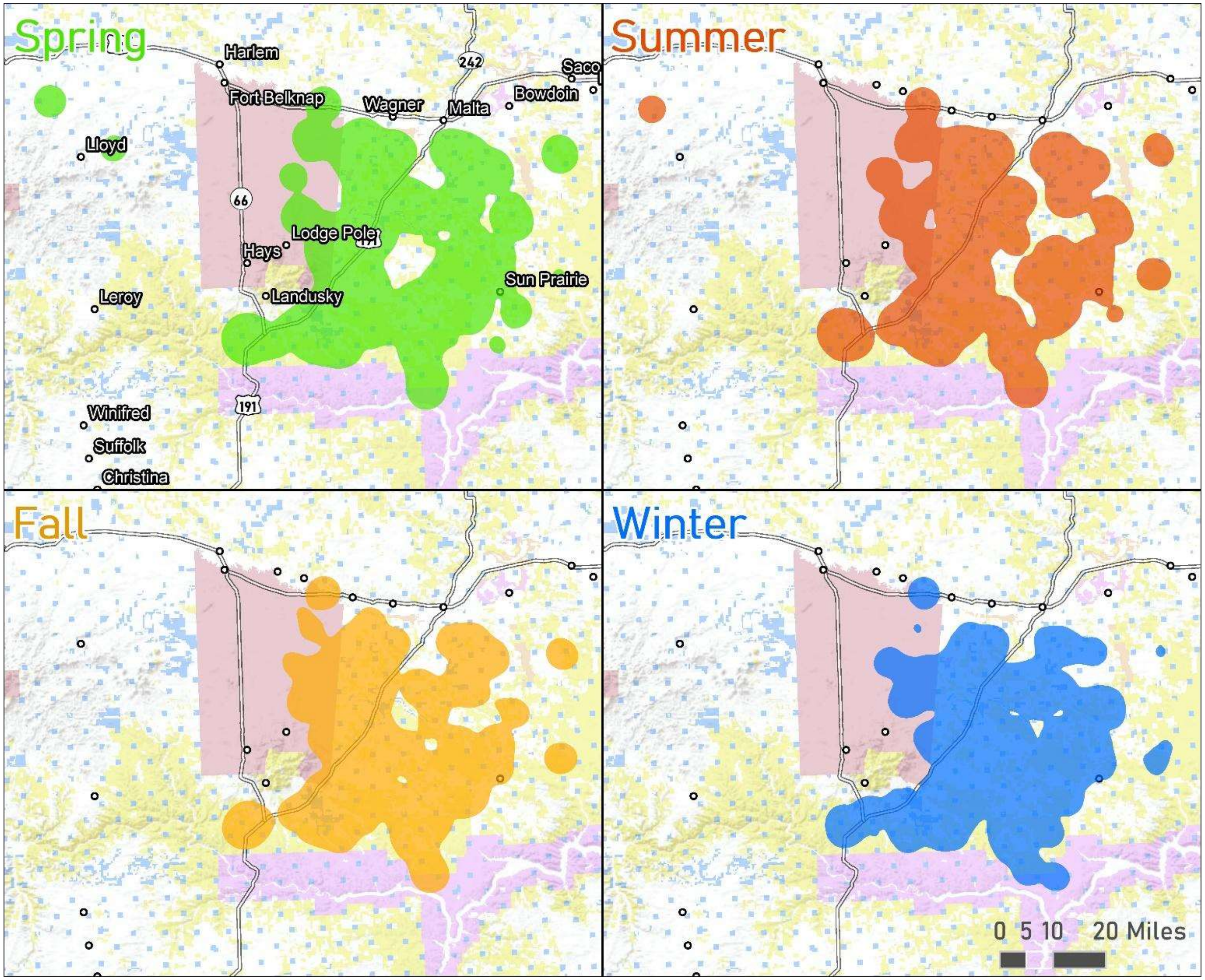


Figure 23. Seasonal ranges of collared adult female pronghorn in the South Philips area for the Montana Pronghorn Movement and Population Ecology Project, as of June 30, 2022. Spring: Apr 1 – Jun 30; Summer: Jul 1 – Aug 31; Fall: Sep 1 – Nov 30; Winter: Dec 1 – Mar 31.

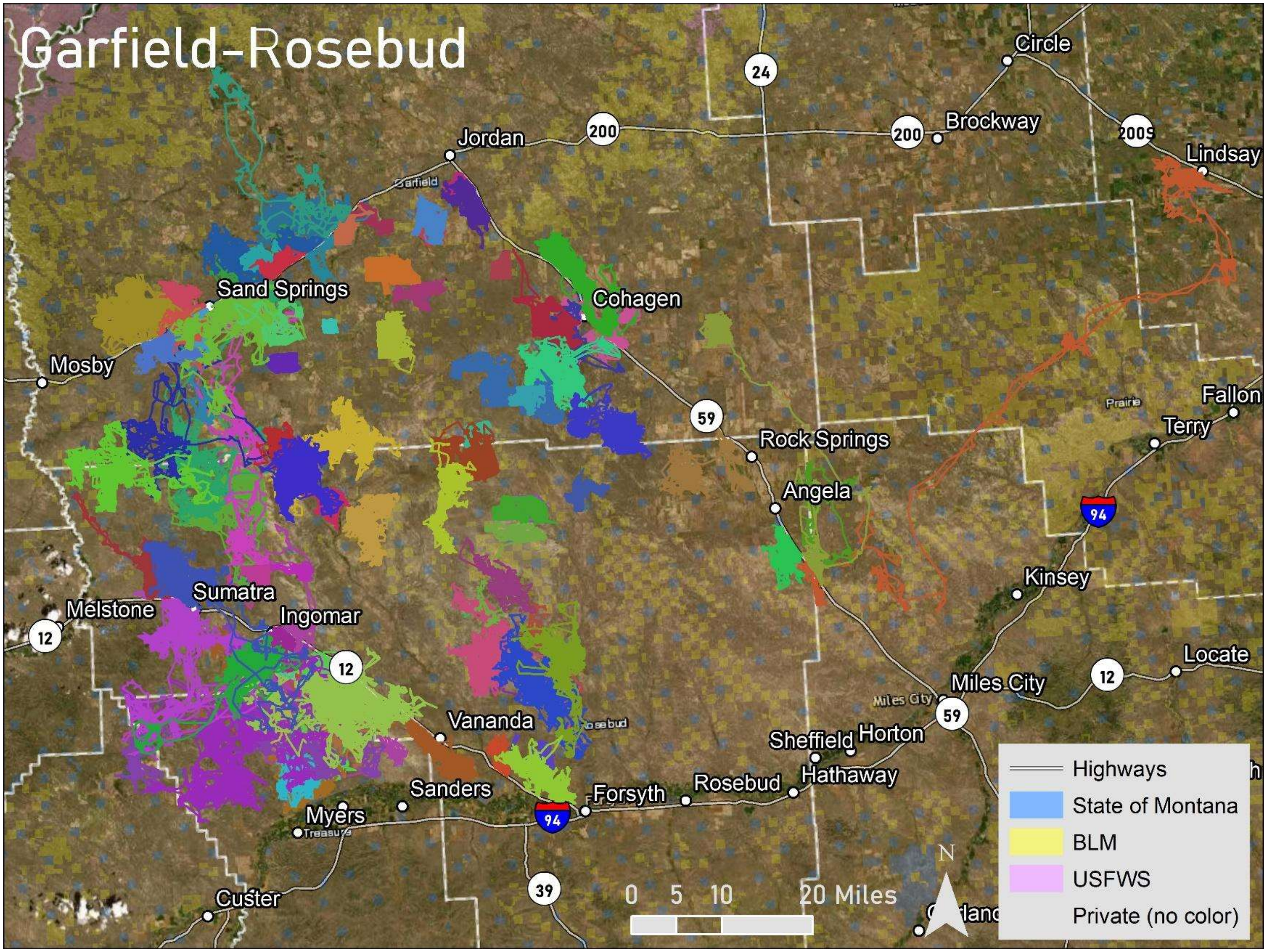


Figure 24. Movements of collared adult female pronghorn (colored by individual) in the Garfield-Rosebud study area for the Montana Pronghorn Movement and Population Ecology Project, as of June 30, 2022.

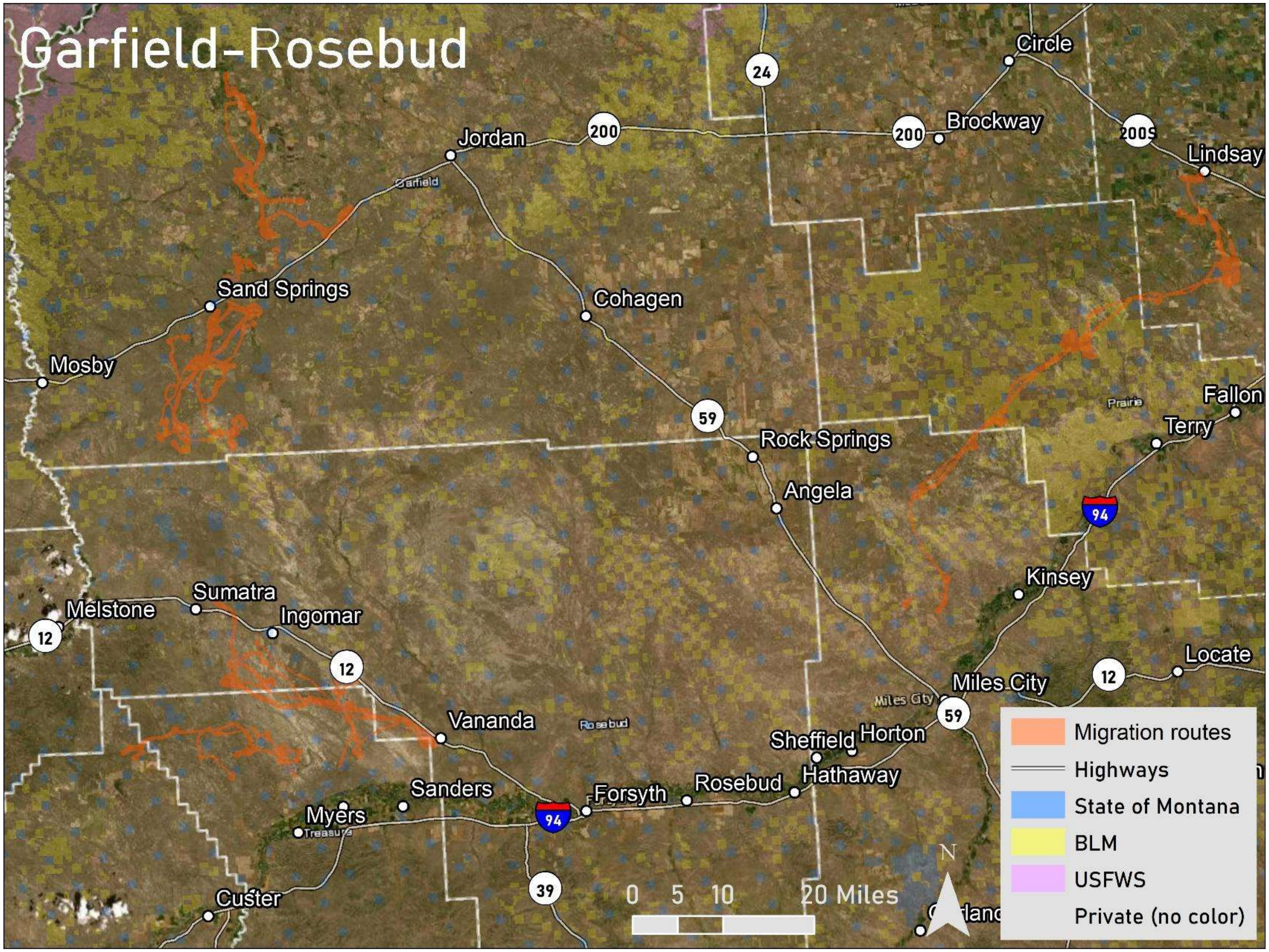


Figure 25. Preliminary estimates of migration routes of migrant collared adult female pronghorn in the Garfield-Rosebud study area for the Montana Pronghorn Movement and Population Ecology Project. Migration routes represent areas used by ≥1 migrant during spring and/or fall migration periods. Individuals with movement data occurring after 01 Feb 2022 are not displayed.

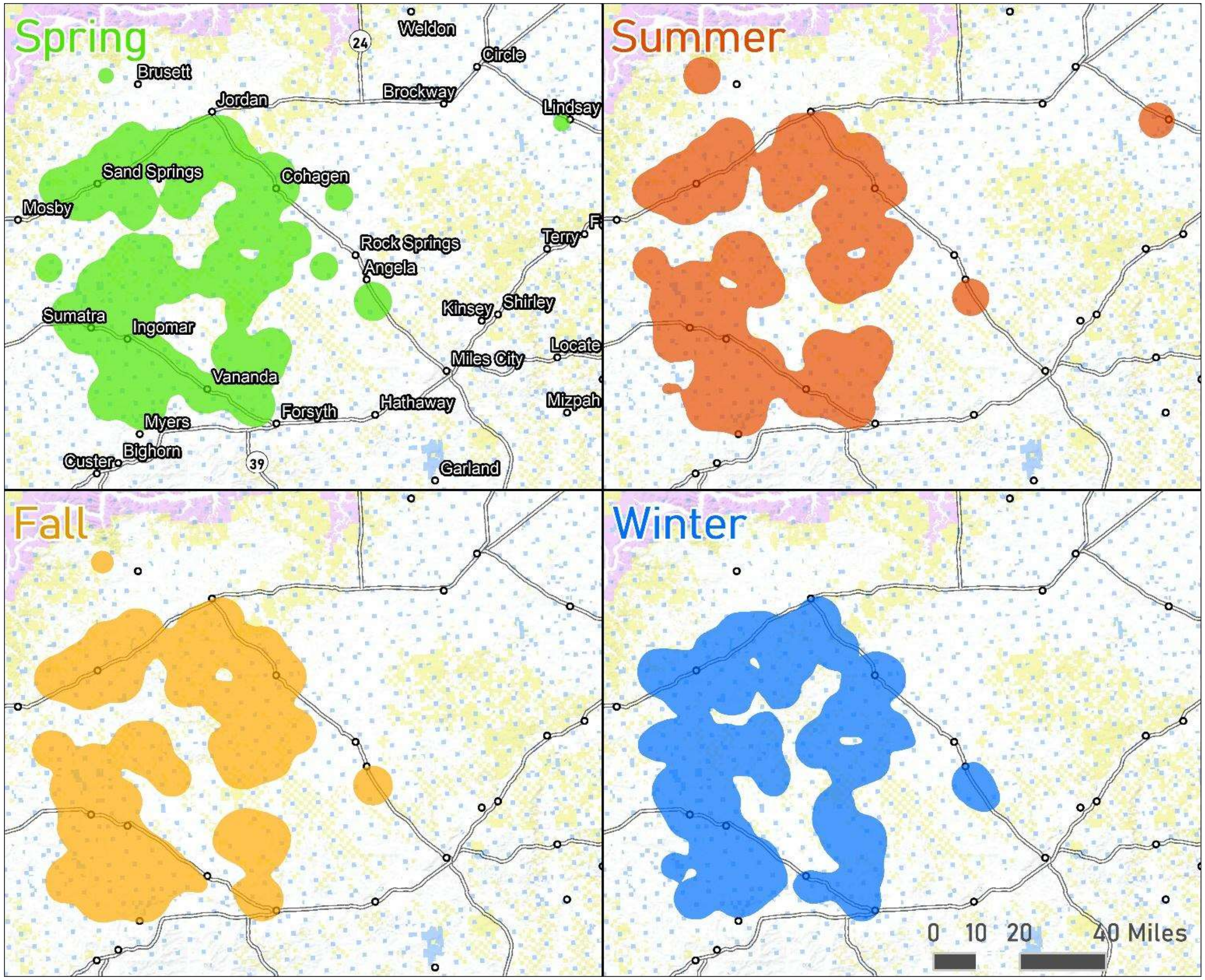


Figure 26. Seasonal ranges of collared adult female pronghorn in the Garfield-Rosebud area for the Montana Pronghorn Movement and Population Ecology Project, as of June 30, 2022. Spring: Apr 1 – Jun 30; Summer: Jul 1 – Aug 31; Fall: Sep 1 – Nov 30; Winter: Dec 1 – Mar 31.

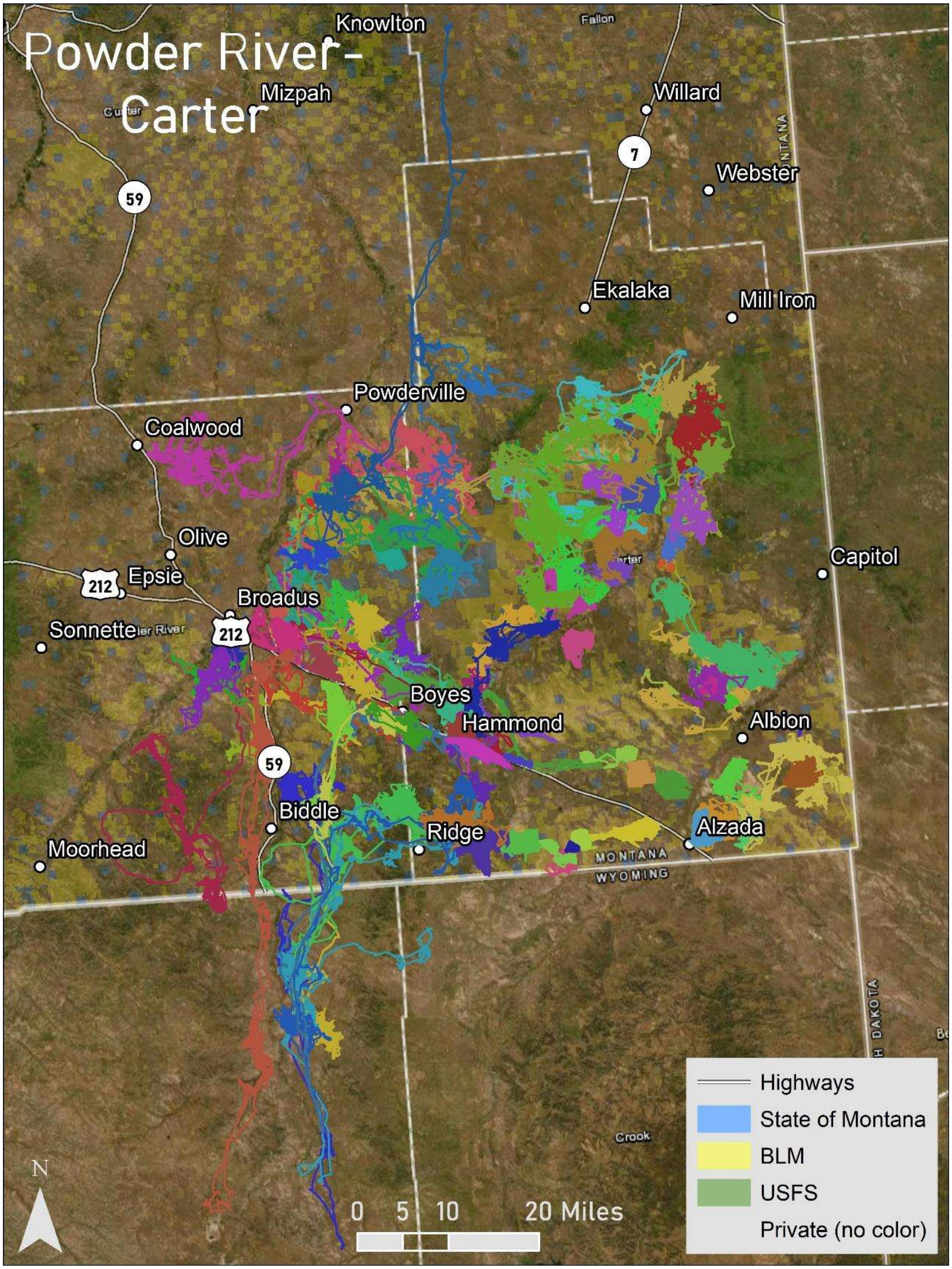


Figure 27. Movements of collared adult female pronghorn (colored by individual) in the Powder River-Carter study area for the Montana Pronghorn Movement and Population Ecology Project, as of June 30, 2022.

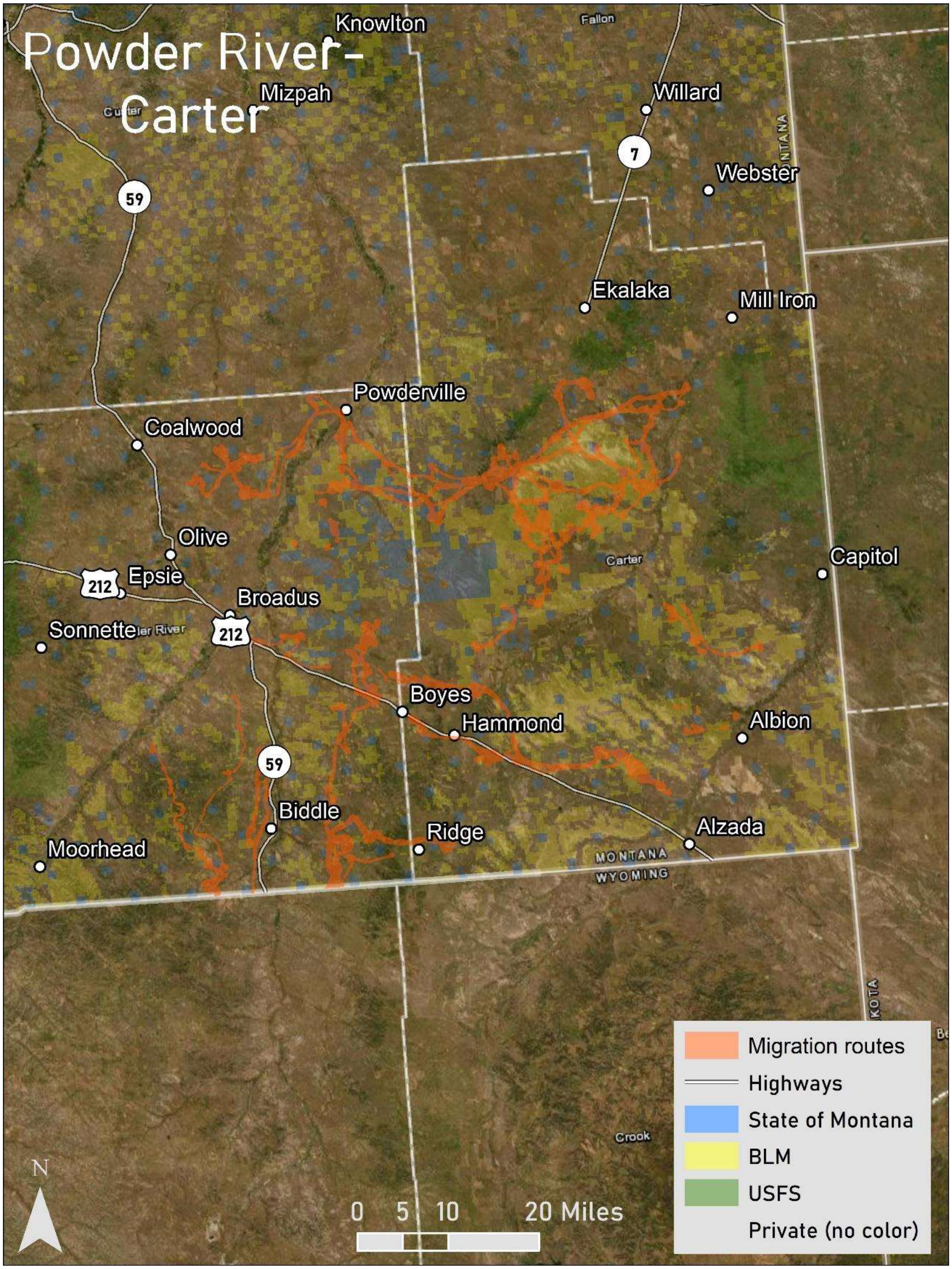


Figure 28. Preliminary estimates of migration routes of migrant collared adult female pronghorn in the Powder River-Carter study area for the Montana Pronghorn Movement and Population Ecology Project. Migration routes represent areas used by ≥1 migrant during spring and/or fall migration periods and are clipped to Montana only. Individuals with movement data occurring after 01 Feb 2022 are not displayed.

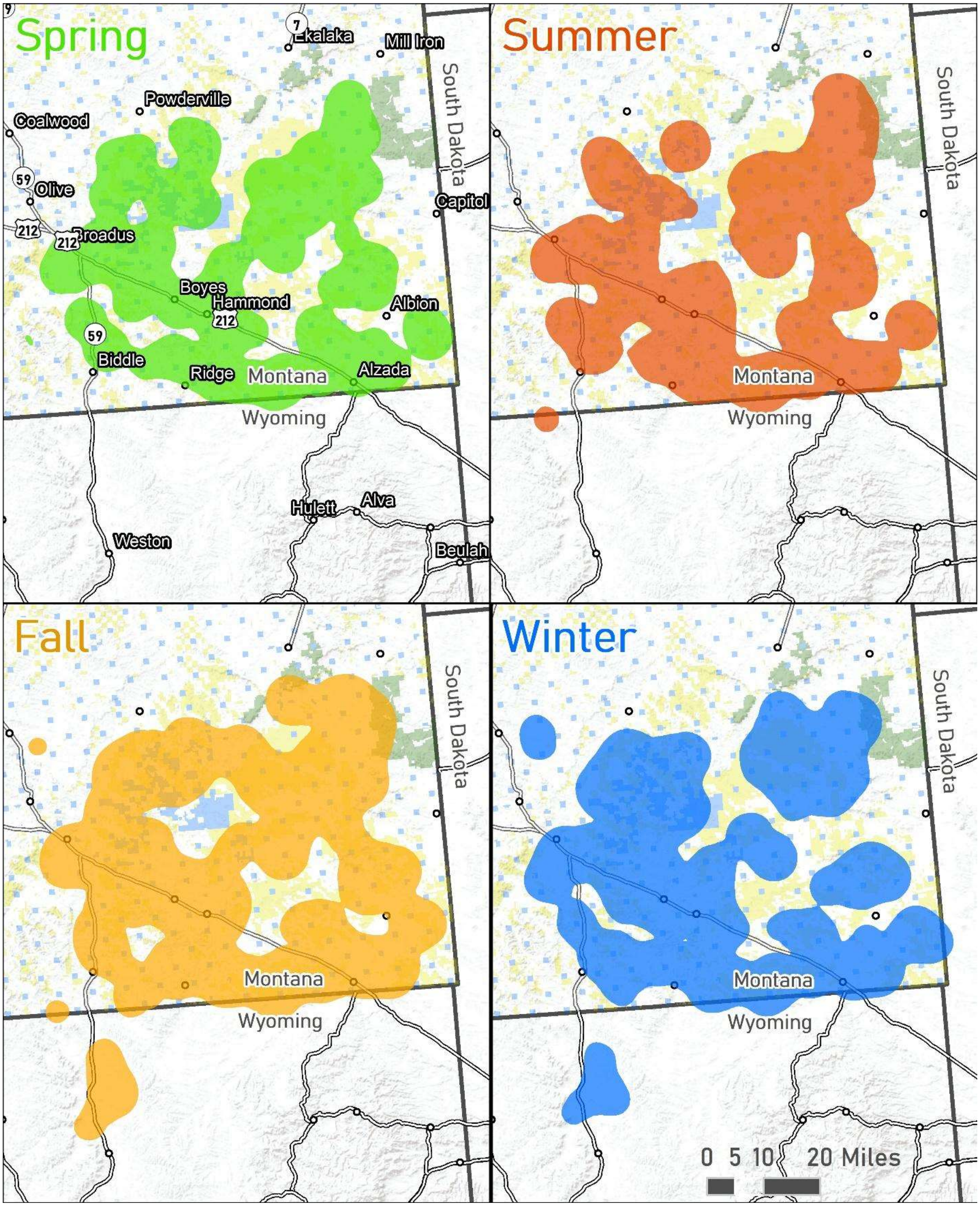


Figure 29. Seasonal ranges of collared adult female pronghorn in the Powder River-Carter area for the Montana Pronghorn Movement and Population Ecology Project, as of June 30, 2022. Spring: Apr 1 – Jun 30; Summer: Jul 1 – Aug 31; Fall: Sep 1 – Nov 30; Winter: Dec 1 – Mar 31.

1.4 Characterizing pronghorn migratory behaviors

To better understand the diversity of individual movement patterns, we characterized migratory strategies for each animal's migratory year, which we selected to span 01 Feb – 31 Jan, with the start of the year representing when individuals are assumed to be on their winter range for that year. We used net squared displacement (NSD; (Bunnefeld et al. 2011, Merkle et al. 2022) curves and maps of movement trajectories for each animal's migratory year to identify migration periods and classify individual pronghorn migratory strategies based on a combination of pre- and post-hoc rules (DeVoe et al. *in preparation*). Initial examinations of NSD curves and movement maps indicated pronghorn demonstrated a variety of migratory movement patterns that included, for example, the use of multiple summer ranges or differing year to year winter ranges. Traditionally, atypical migratory behaviors are forced into more generic categories or ignored (Cagnacci et al. 2016), even though these atypical behaviors are considered to be relatively common across ungulate species and critical for population persistence under changing environmental conditions (Cagnacci et al. 2016, van de Kerk et al. 2021, Xu et al. 2021*a*). We therefore adopted and expanded upon classification methods developed by van de Kerk et al. (2021) for classifying variable migratory behaviors (Figure 30).

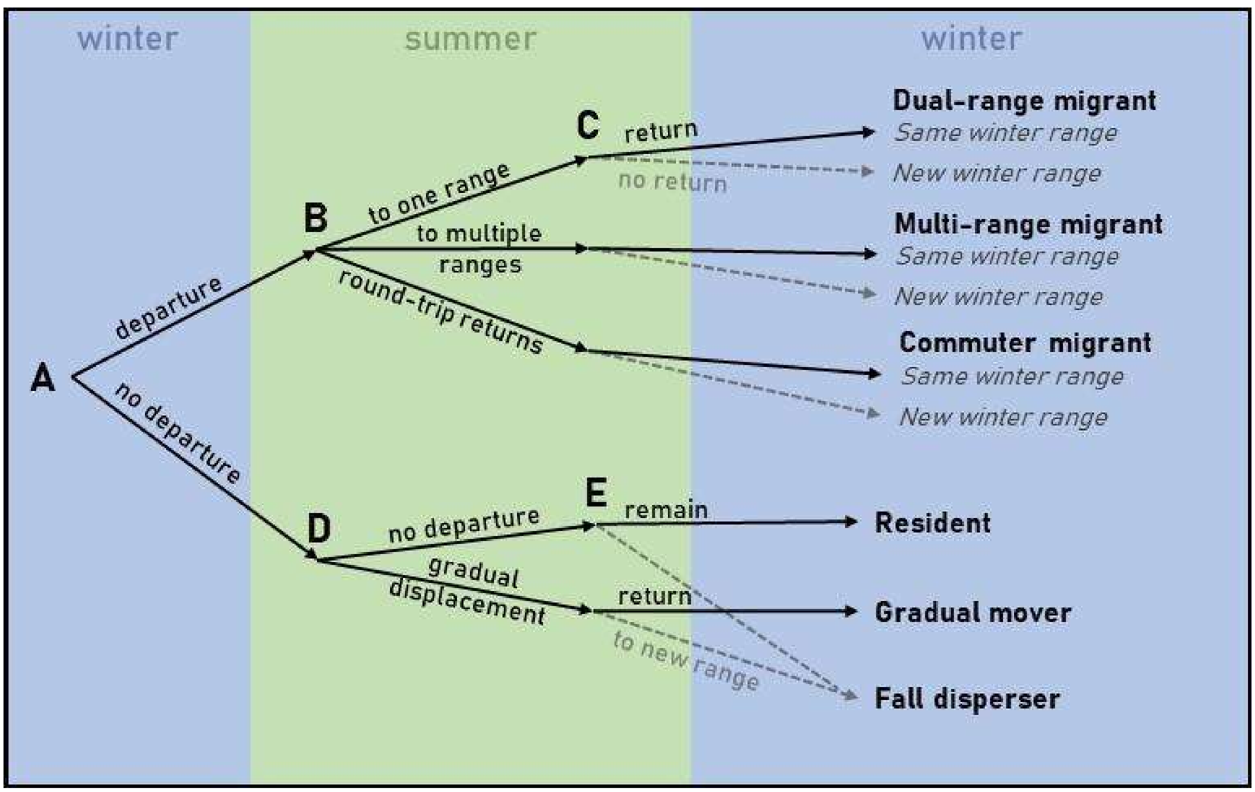


Figure 30. Decision tree adapted from van de Kerk et al. (2021) indicating how we categorized migration strategies from movement trajectories of each animal's migratory year (Feb 01 – Jan 31) for pronghorn captured between 2019 and 2021 in Montana, USA.

We classified animal-years into 6 categories to capture the highly variable migratory behaviors observed in our pronghorn, that included dual-range migrant, multi-range migrant, commuter migrant, resident, gradual mover, or fall disperser. We defined *dual-range migrants* as those that made only one visit to a single summer range before returning to winter range. *Multi-range migrants* visited multiple summer ranges before returning to winter range. *Commuter migrants* made multiple (≥2) roundtrips during the summer between at least one summer range and their initial winter range. *Residents* did not depart their initial winter range and remained on one range the entire year, while *gradual movers* made a slow, indistinct movement outside of a typical home range, as determined by their NSDs surpassing 104 km for at least 21 days. We selected this threshold based on the median annual home range size of 104.1 km^2 calculated from a 95% kernel density estimate of locations for each animal-year in our study. *Fall dispersers* did not depart their initial winter range until fall, when they dispersed to a new winter range. For migrant classifications, we additionally recorded whether animals returned to their initial winter range during the fall (i.e., *same winter range*) or occupied a new final winter range (i.e., *new winter range*), which could include a non-departure from their final summer range or a range shift to an alternate winter range. For migrants with multiple years of data, we recorded whether they returned to their initial summer ranges (i.e., *same summer range*) or shifted to a different summer range in the subsequent year (i.e., *new summer range*). Last, we measured migration distances for each migrant using only the outbound spring migration trajectories, visually examining movement maps to identify the areas of the winter and summer ranges that contained the overall concentration of locations, and measured the Euclidean distance between the edges of the concentrated areas, generally following the animal's spring migratory pathway to account for topographic diversions (e.g., animal pathways circuiting a mountain range separating its winter). For animals with multiple distinct summer ranges, we measured the distance to the furthest summer range.

Of the 702 collared pronghorn, a total of 439 individuals and 688 animal-years (29, 301, and 358 animal-years for 2019, 2020, and 2021, respectively) had sufficient data (i.e., 365 days) to characterize migratory strategies. Of these individuals, 207 (47.2%), 215 (49.0%), and 17 (3.9%) had 1, 2, and 3 animal-years of data, respectively. The number of animal-years per study area averaged 86.0 and ranged from 39 in Paradise to 118 in Madison. Across all animal-years and study areas, departure and arrival dates of migratory individuals (i.e., those that departed their initial winter range) respectively averaged 06 Apr (range = 21 Feb – 16 Jul) and 15 Apr (range = 24 Feb – 30 Jul) for spring and 15 Oct (range = 14 Jul – 20 Dec) and 22 Oct (range = 17 Jul – 08 Jan) for fall (Figure 31). Departure and arrival dates of migratory individuals for spring and fall varied by year (Figure 32) and study area (Table 3, Figure 33). Migration distances averaged 44.3 km (median = 32.0, SD = 34.2, range = 10 – 160) across study areas and varied by study area (Figure 34).

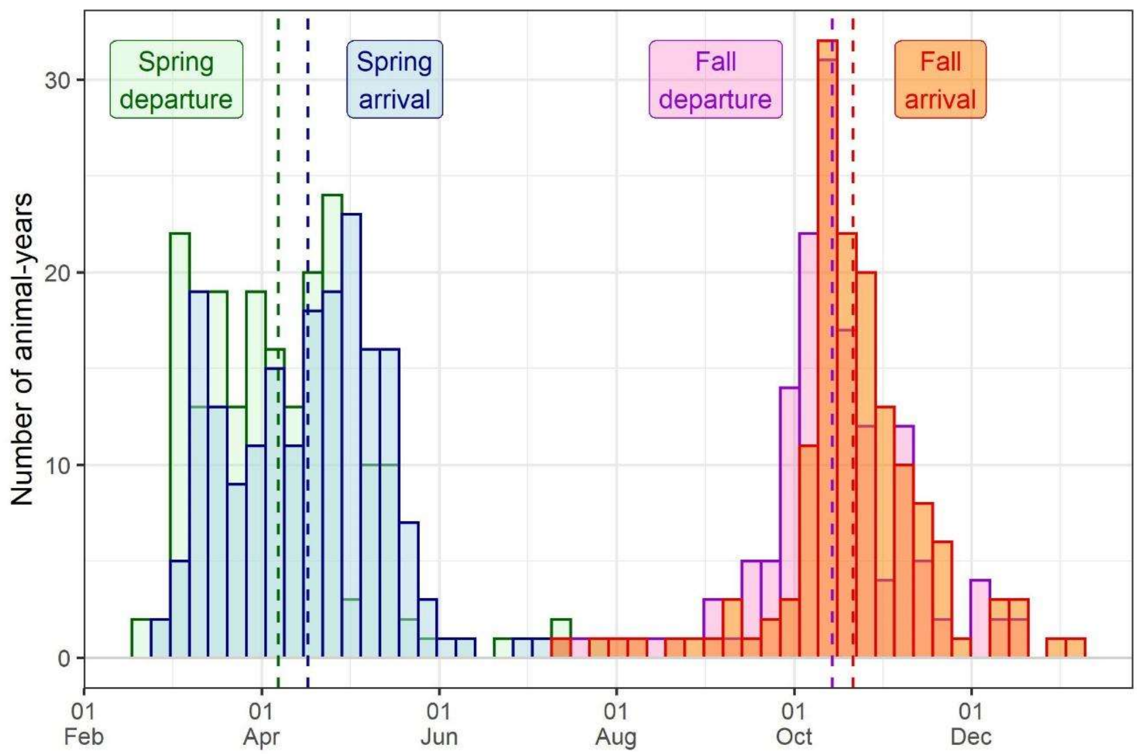


Figure 31. Distribution and average (vertical dashed lines) of migratory departure and arrival days for spring and fall migrations across all years and study areas of migratory pronghorn captured between 2019 and 2021 in Montana, USA.

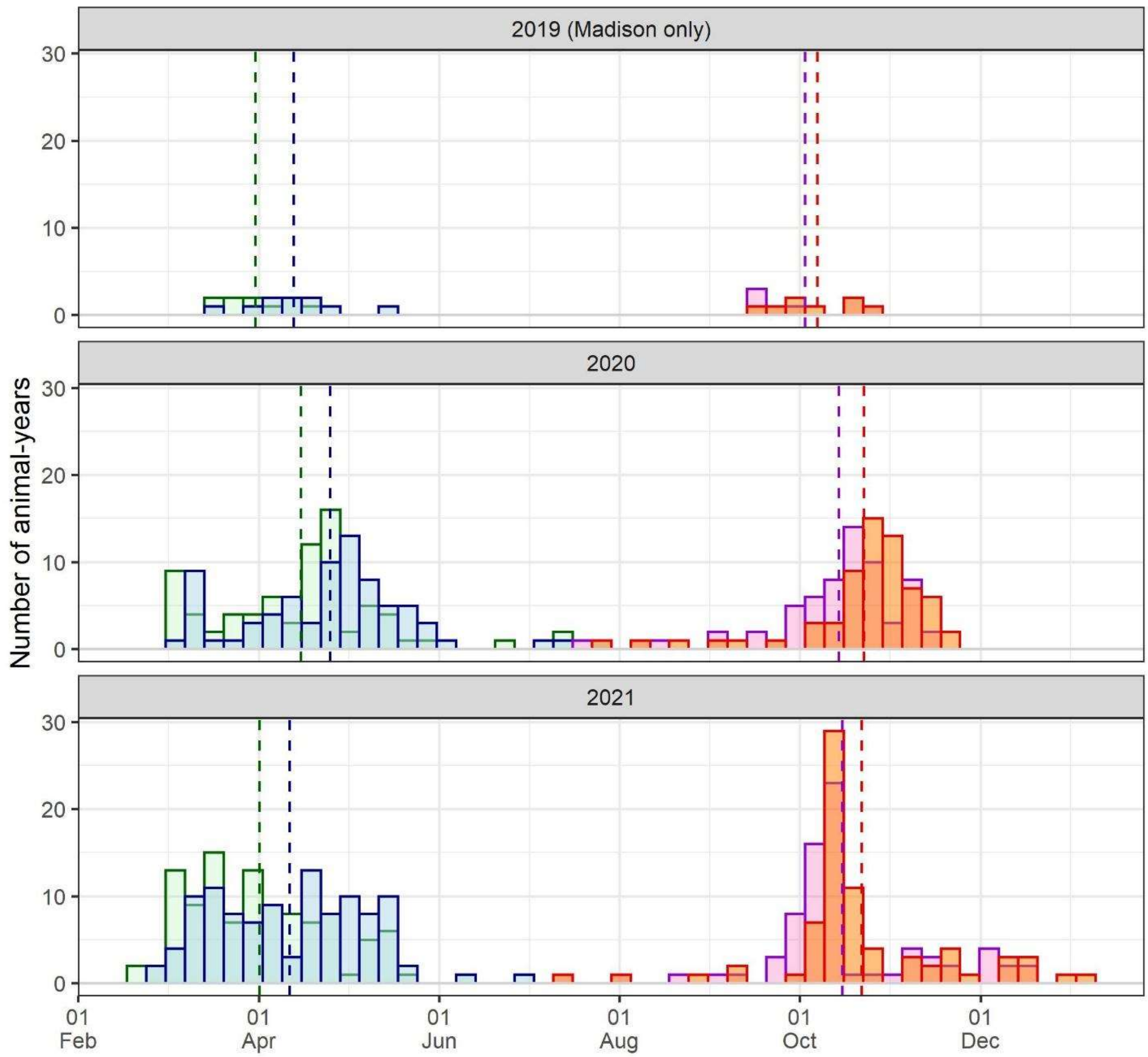


Figure 32. Distribution and average (vertical dashed lines) of dates of spring departure (green), spring arrival (blue), fall departure (purple), and fall arrival (orange) for each year across all study areas of migratory pronghorn captured between 2019 and 2021 in Montana, USA.

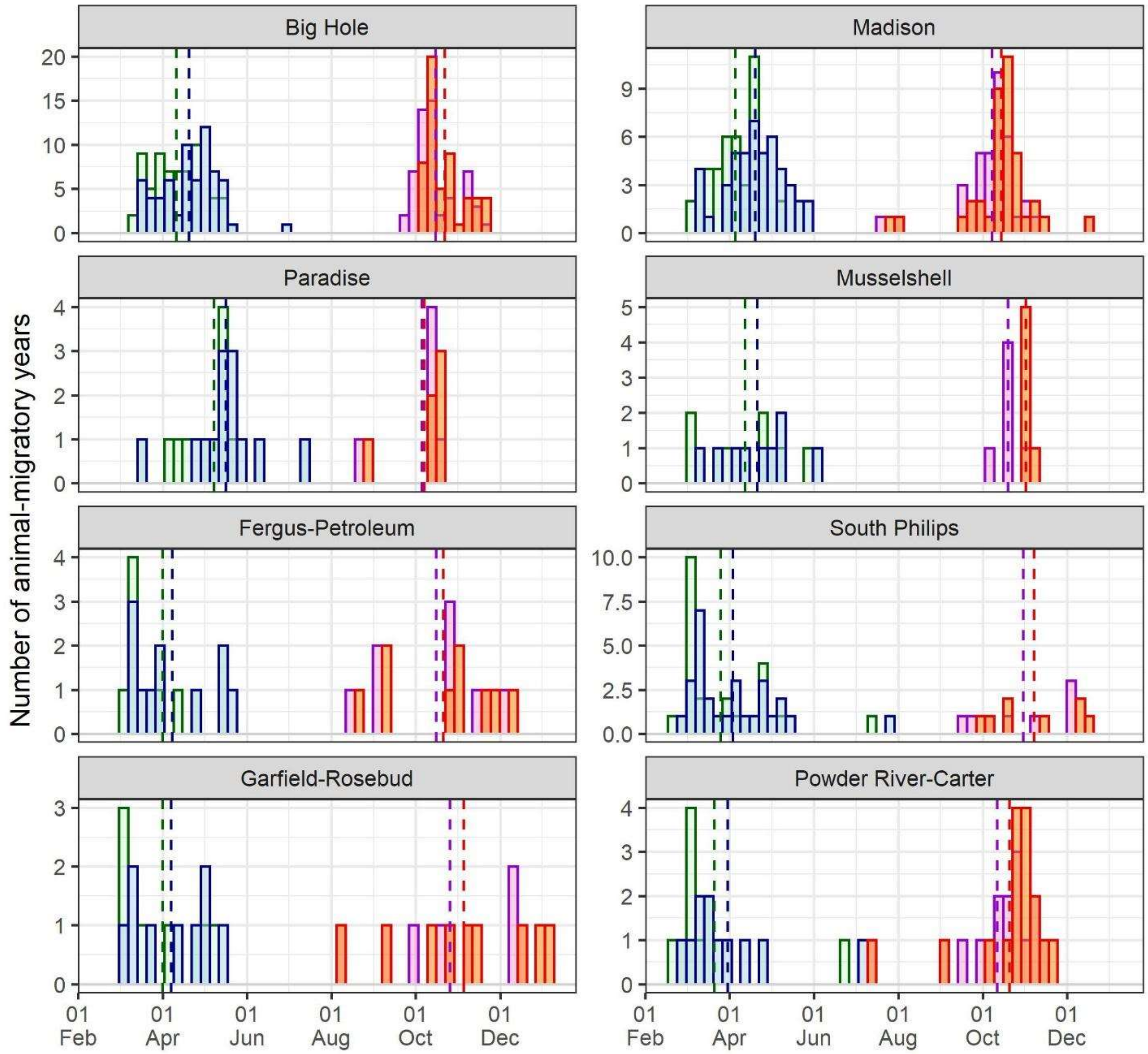


Figure 33. Distribution and average (vertical dashed lines) of dates of spring departure (green), spring arrival (blue), fall departure (purple), and fall arrival (orange) across years for each study areas of migratory pronghorn captured between 2019 and 2021 in Montana, USA. Note different y-axis scales.

Table 3. Average and range of migratory departure and arrival dates for spring and fall migrations for each study area of pronghorn captured between 2019 and 2021 in Montana, USA.

Study area	Spring		Fall	
	Mean departure	Mean arrival	Mean departure	Mean arrival
Big Hole	10 Apr (12 Mar - 23 May)	20 Apr (17 Mar - 29 Jun)	15 Oct (22 Sep - 18 Nov)	22 Oct (06 Oct - 21 Nov)
Madison	05 Apr (04 Mar - 08 May)	19 Apr (08 Mar - 28 May)	07 Oct (22 Jul - 14 Dec)	14 Oct (23 Jul - 15 Dec)
Paradise	08 May (16 Mar - 13 Jul)	16 May (18 Mar - 16 Jul)	05 Oct (24 Aug – 17 Oct)	07 Oct (27 Aug - 18 Oct)
Musselshell	12 Apr (03 Mar - 28 May)	20 Apr (08 Mar - 02 Jun)	19 Oct (05 Oct - 31 Oct)	01 Nov (29 Oct - 08 Nov)
Fergus-Petroleum	31 Mar (02 Mar - 18 May)	07 Apr (08 Mar - 20 May)	15 Oct (14 Aug - 06 Dec)	20 Oct (19 Aug - 08 Dec)
South Philips	25 Mar (21 Feb - 15 Jul)	03 Apr (25 Feb - 29 Jul)	30 Oct (17 Sep - 04 Dec)	06 Nov (01 Oct - 16 Dec)
Garfield-Rosebud	31 Mar (03 Mar - 11 May)	07 Apr (06 Mar - 13 May)	25 Oct (09 Aug - 19 Dec)	04 Nov (11 Aug - 07 Jan)
Powder River-Carter	20 Mar (22 Feb - 21 Jun)	30 Mar (24 Feb - 04 Jul)	11 Oct (13 Jul - 17 Nov)	20 Oct (16 Jul - 18 Nov)

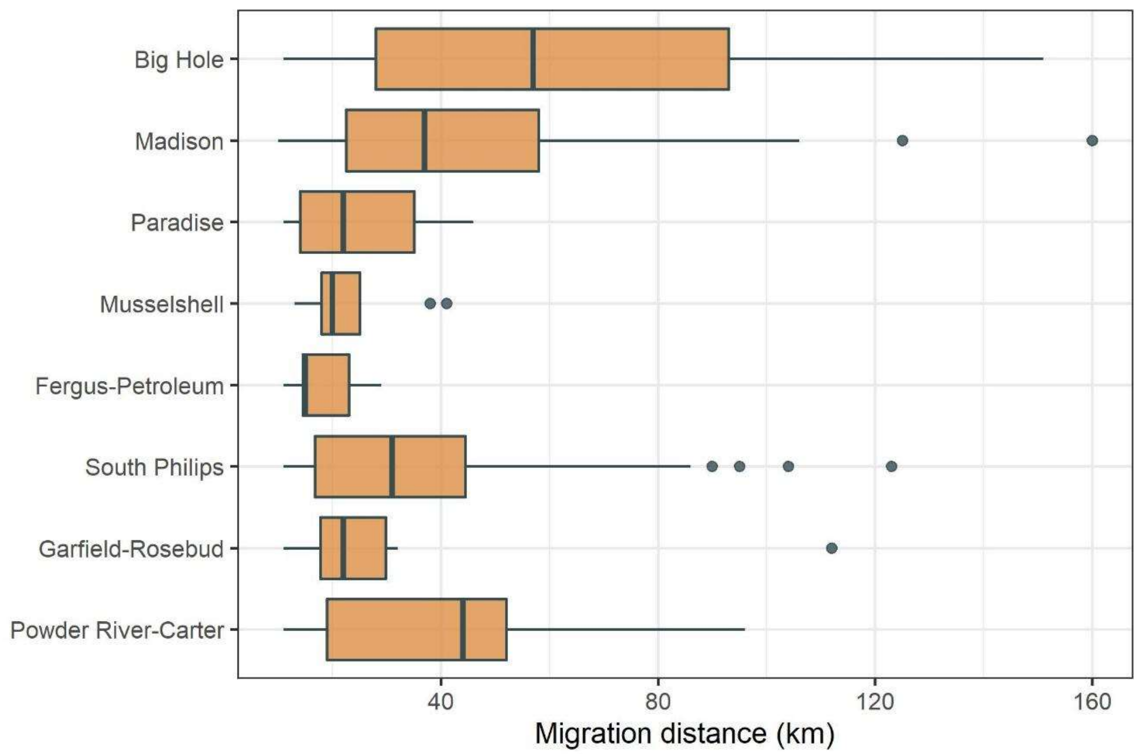


Figure 34. Distributions of migratory distances of migratory individuals in each study area of pronghorn captured between 2019 and 2021 in Montana, USA. Distances were measured following the animal's spring migratory pathway to its furthest summer range. Vertical lines through boxes represent median values, the length of the box represents the interquartile range (IQR; i.e., the middle 50% of observations) and horizontal lines represent values within 1.5x the IQR.

Across all study areas and years, the majority of individuals (n = 528, 76.7%) did not distinctly depart their initial winter range during the summer, with over half of all pronghorn (n = 404, 58.7% of total) remaining as residents, 85 (12.4% of total) exhibiting gradual range shifts as gradual movers, and 39 (5.7% of total) departing to new winter ranges during the fall (i.e., fall dispersers; Figure 34). The percent of individuals classified as either resident, gradual mover, or fall disperser each year ranged from 25.0% in Big Hole to 94.6% in Powder River-Carter (Table 4).

The remainder of individuals, comprising approximately a fifth of all pronghorn (n = 160, 23.3%), distinctly departed their initial winter range and moved to summer range, with 99 (61.9% of those departed) returning to the initial winter range and 61 (38.1% of those departed) dispersing to a new winter range. Of those that returned to their initial winter range, 79 (11.5% of total) were classified as dual-range migrants, 17 (2.5% of total) were classified as multi-range migrants, and 3 (0.4% of total) were classified as commuter migrants. Proportions of migratory classifications varied by study area and year (Figure 35 and 36; Table 4). Across all migratory strategies, the percent of individuals returning to their initial winter range each year ranged from 66.7% in Big Hole to 100% in Paradise. Of the individuals that had enough data to determine summer range fidelity in subsequent years (n = 251), the percent of individuals returning to their initial summer range each year ranged from 92.0% in Powder River-Carter to 100% in Big Hole, Madison, Paradise, Musselshell, Fergus-Petroleum, and Garfield-Rosebud.

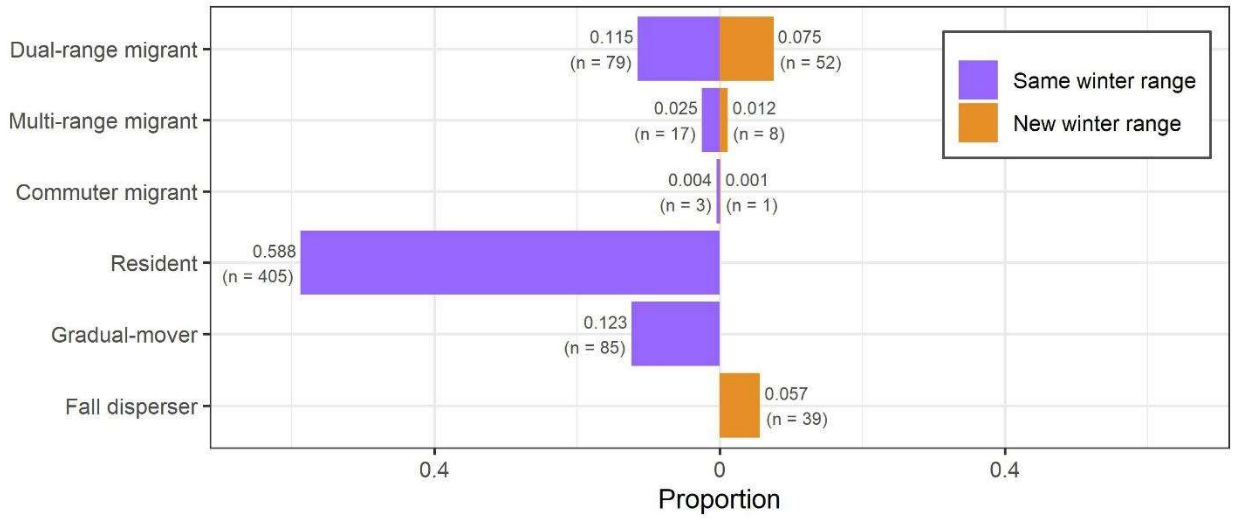


Figure 35. Proportion of animals classified into migratory strategy classes and whether they returned to their original (purple) or a new (orange) winter range across years and study areas of pronghorn captured between 2019 and 2021 in Montana, USA.

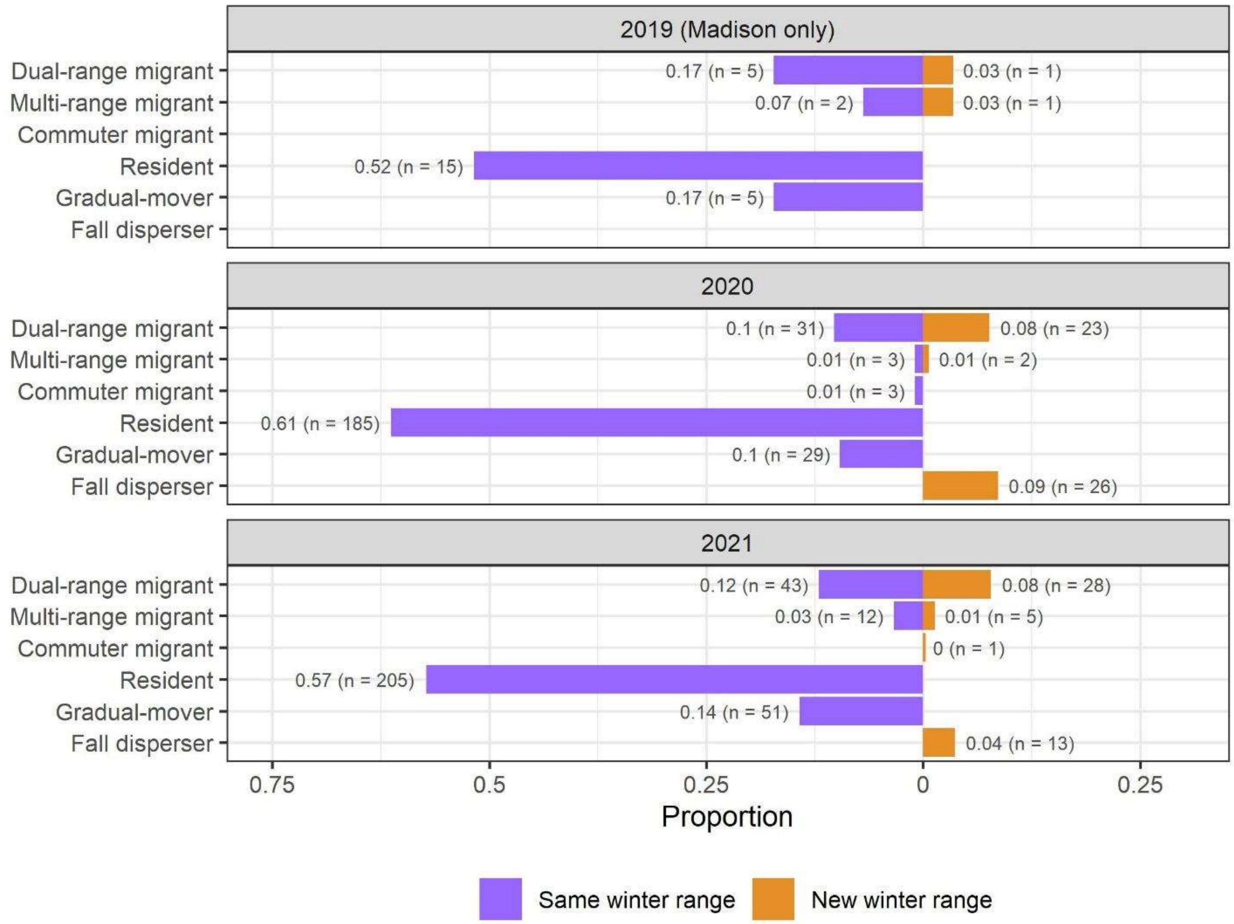


Figure 36. Proportion of animals classified into migratory strategy classes and whether they returned to their original (purple) or a new (orange) winter range for each year across study areas of pronghorn captured between 2019 and 2021 in Montana, USA.

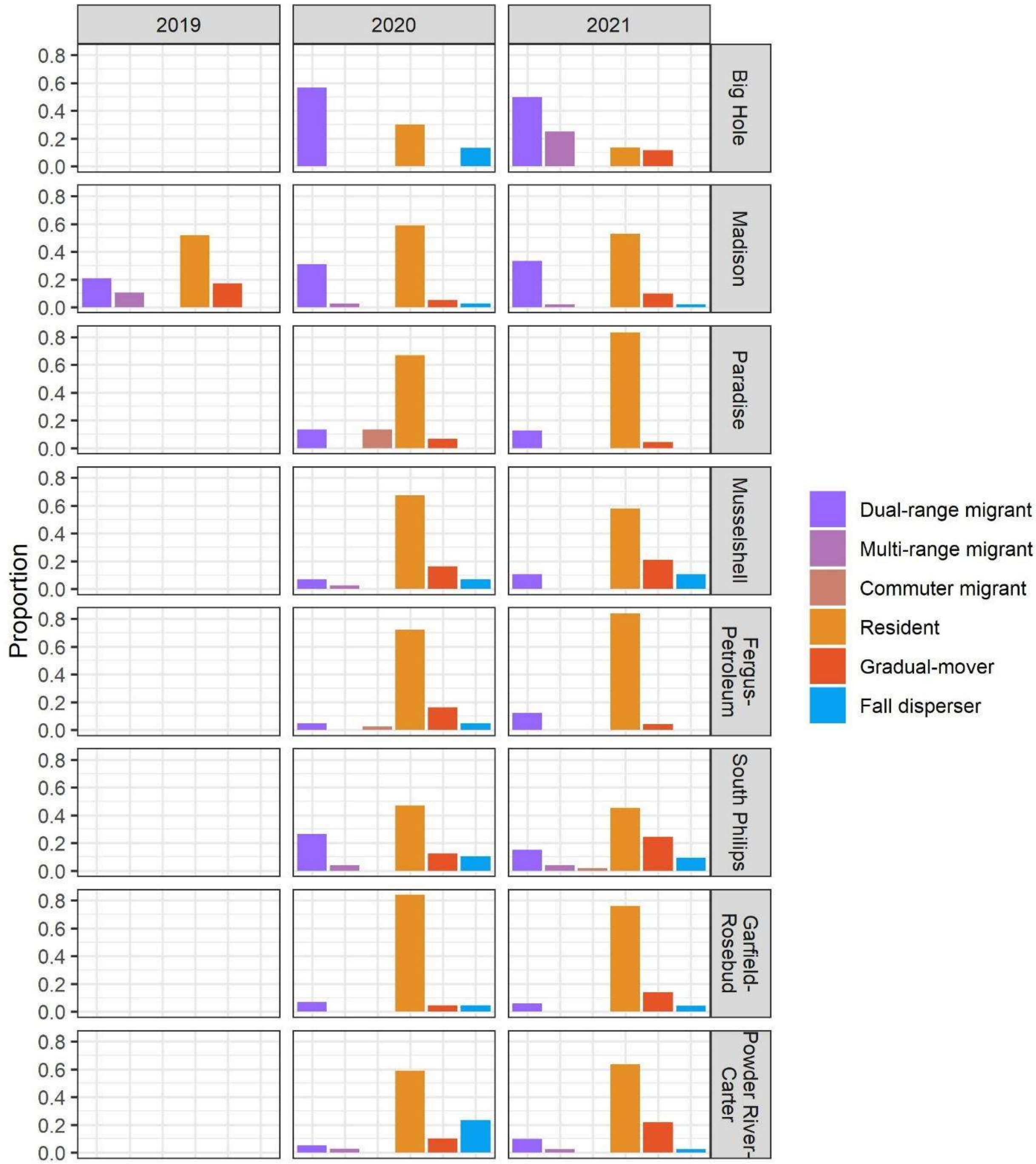


Figure 37. Proportion of animals classified into migratory strategy classes for each year and study area of pronghorn captured between 2019 and 2021 in Montana, USA.

Table 4. Number and proportion of animals classified into each migratory class for each year and study area of pronghorn captured between 2019 and 2021 in Montana, USA.

Study area	Migration behavior	2019	2020	2021
Big Hole	Dual-range migrant	--	17 (0.57)	26 (0.50)
	Multi-range migrant	--	--	13 (0.25)
	Resident	--	9 (0.30)	7 (0.13)
	Gradual-mover	--	--	6 (0.12)
	Fall disperser	--	4 (0.13)	--
	Total	--	30	52
Madison	Dual-range migrant	6 (0.21)	12 (0.32)	17 (0.33)
	Multi-range migrant	3 (0.10)	1 (0.03)	1 (0.02)
	Resident	15 (0.52)	22 (0.58)	28 (0.54)
	Gradual-mover	5 (0.17)	2 (0.05)	5 (0.10)
	Fall disperser	--	1 (0.03)	1 (0.02)
	Total	29	38	52
Paradise	Dual-range migrant	--	2 (0.13)	3 (0.12)
	Commuter migrant	--	2 (0.13)	--
	Resident	--	10 (0.67)	20 (0.83)
	Gradual-mover	--	1 (0.07)	1 (0.04)
	Total	--	15	24
Musselshell	Dual-range migrant	--	3 (0.07)	4 (0.11)
	Multi-range migrant	--	1 (0.02)	--
	Resident	--	29 (0.67)	22 (0.58)
	Gradual-mover	--	7 (0.16)	8 (0.21)
	Fall disperser	--	3 (0.07)	4 (0.11)
	Total	--	43	38
Fergus-Petroleum	Dual-range migrant	--	2 (0.05)	6 (0.12)
	Commuter migrant	--	1 (0.02)	--
	Resident	--	31 (0.72)	41 (0.84)
	Gradual-mover	--	7 (0.16)	2 (0.04)
	Fall disperser	--	2 (0.05)	--
	Total	--	43	49
South Philips	Dual-range migrant	--	13 (0.27)	8 (0.15)
	Multi-range migrant	--	2 (0.04)	2 (0.04)
	Commuter migrant	--	--	1 (0.02)
	Resident	--	23 (0.47)	24 (0.45)
	Gradual-mover	--	6 (0.12)	13 (0.25)
	Fall disperser	--	5 (0.10)	5 (0.09)
	Total	--	49	53
Garfield-Rosebud	Dual-range migrant	--	3 (0.07)	3 (0.06)
	Resident	--	37 (0.84)	38 (0.76)
	Gradual-mover	--	2 (0.05)	7 (0.14)
	Fall disperser	--	2 (0.05)	2 (0.04)
	Total	--	44	50
Powder River-Carter	Dual-range migrant	--	1 (0.03)	4 (0.10)
	Multi-range migrant	--	1 (0.03)	1 (0.02)
	Resident	--	22 (0.59)	26 (0.63)
	Gradual-mover	--	4 (0.11)	9 (0.22)
	Fall disperser	--	9 (0.24)	1 (0.02)
	Total	--	37	41

We observed 82 instances of individuals switching migratory strategies from one year to the next (Figures 38 - 43). From a total of 22 individuals classified for 2019 and 2020 (i.e., Madison study area only), 5 (21.7%) individuals switched, including 1 from dual-range migrant to multi-range migrant, 1 from dual-range migrant to resident, 2 from gradual-mover to resident, and 1 from gradual-mover to dual-range migrant (Figure 38 [panel A] and Figure 40). Of these, 17 individuals were also classified for 2021 from which 4 (23.5%) switched, including 1 from dual-range migrant to fall disperser, 1 multi-range migrant to dual-range migrant, and 2 residents to gradual-movers (Figure 40). From a total of 227 individuals classified for 2020 and 2021, 77 (33.9%) animals switched (Figures 38 [panel B] – 39 and Figures 41 – 43). The vast majority of these animals switched from resident to gradual-mover (n = 16, 20.8%), gradual-mover to resident (n = 16, 20.8%), and fall disperser to dual-range migrant (n = 11, 14.3%). The remainder included 13 (16.9%) switches between migrant and non-departure classes (4 dual-range migrant to resident, 5 dual-range migrants to gradual-movers, 2 dual-range migrants to fall dispersers, 1 multi-range to resident, and 1 gradual-mover to multi-range migrant) and 9 (11.7%) between migrant classes (4 dual-range migrant to multi-range migrant, 1 dual-range migrant to commuter migrant, 2 multi-range migrant to dual-range migrant, 2 commuter migrants to dual-range migrants).

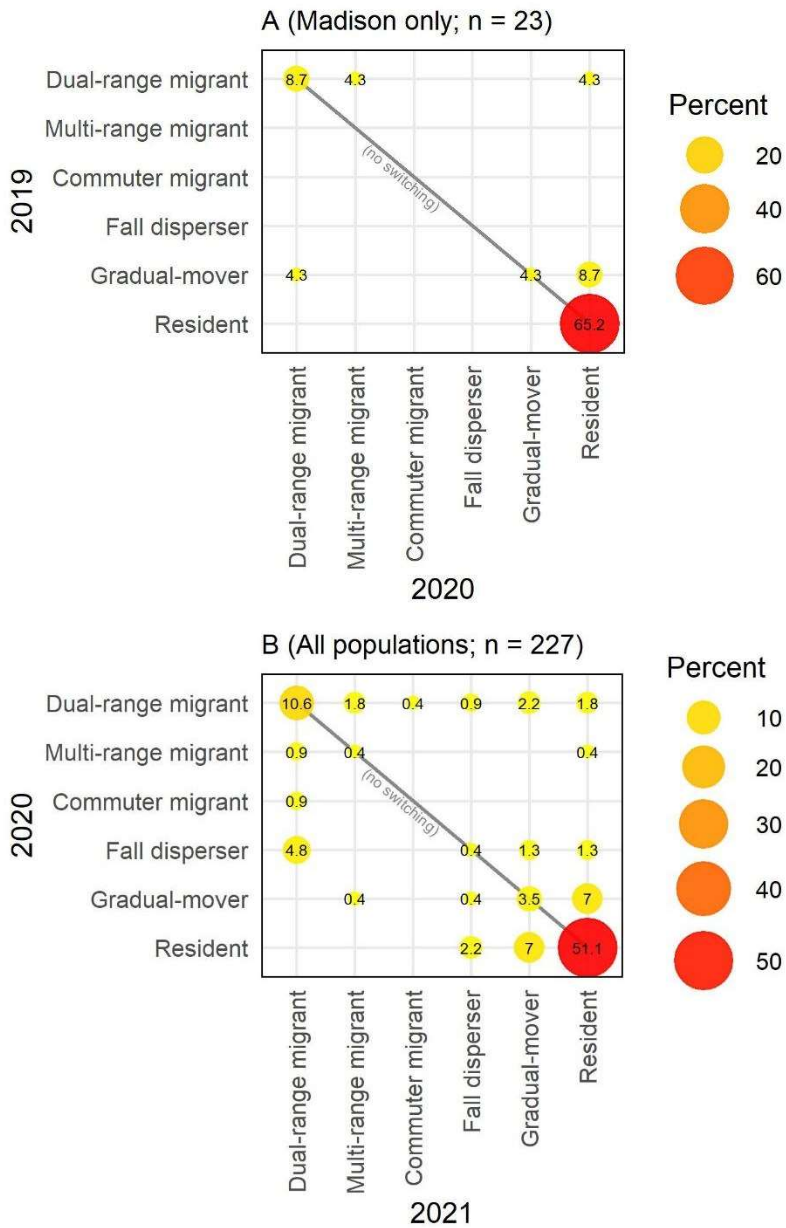


Figure 38. Percent of migratory strategy classification switches between years 2019 and 2020 (panel A) and 2020 and 2021 (panel B) of individual pronghorn captured between 2019 and 2021 in Montana, USA. The migratory strategy occurring in the first year occur on the y-axis and in the second year occur on the x-axis. Values occurring along the diagonal line represent proportions of individuals that did not switch between the years. Sample sizes (n) represent total number of individuals (i.e., including both switching and non-switching individuals)

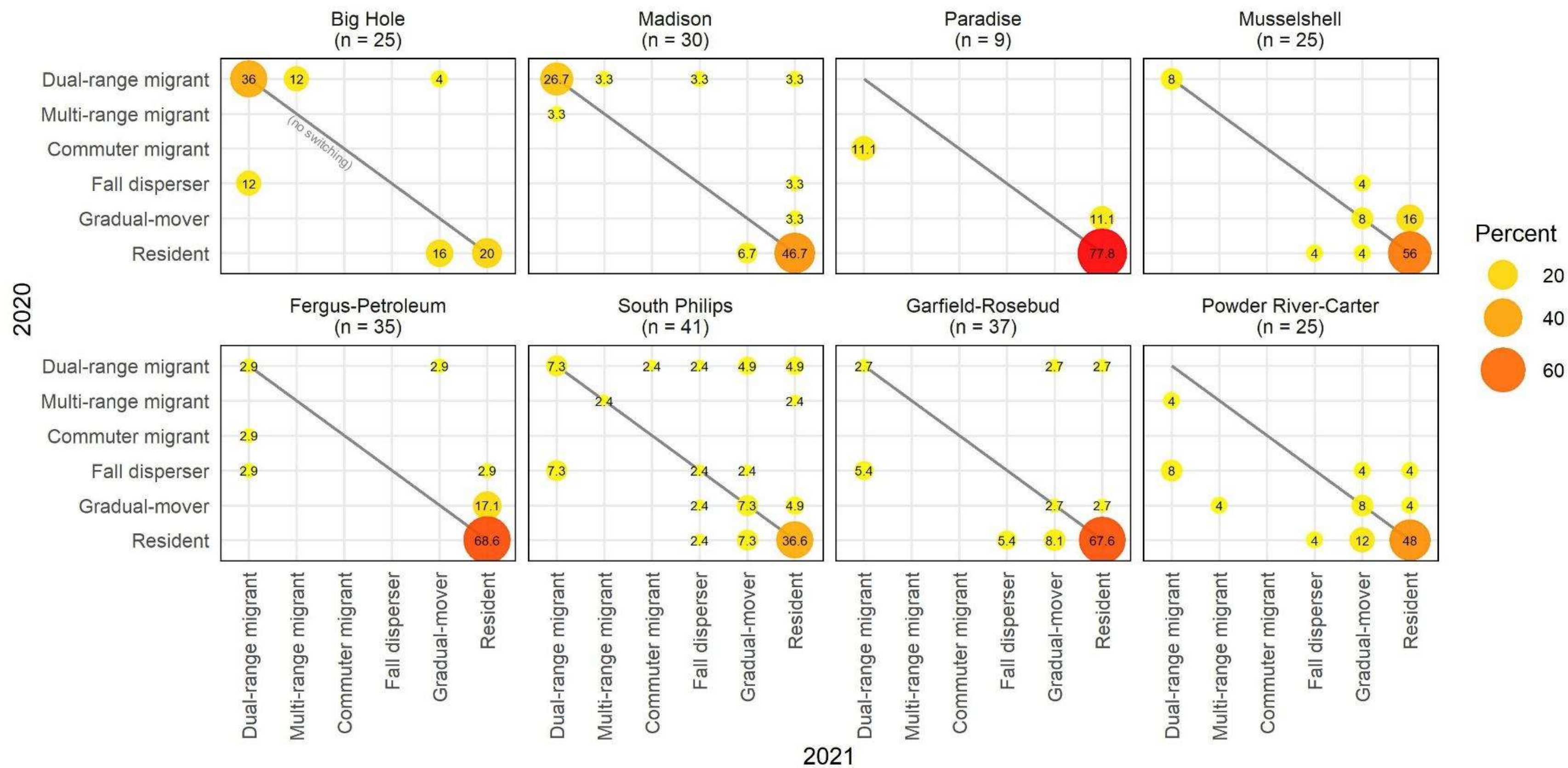


Figure 39. Percent of migratory strategy classification switches between years 2020 (y-axis) and 2021 (x-axis) in each study area of pronghorn captured between 2019 and 2021 in Montana, USA. Values occurring along the diagonal line represent proportions of individuals that did not switch between the years. Sample sizes (n) represent total number of individuals in each study area (i.e., including both switching and non-switching individuals).

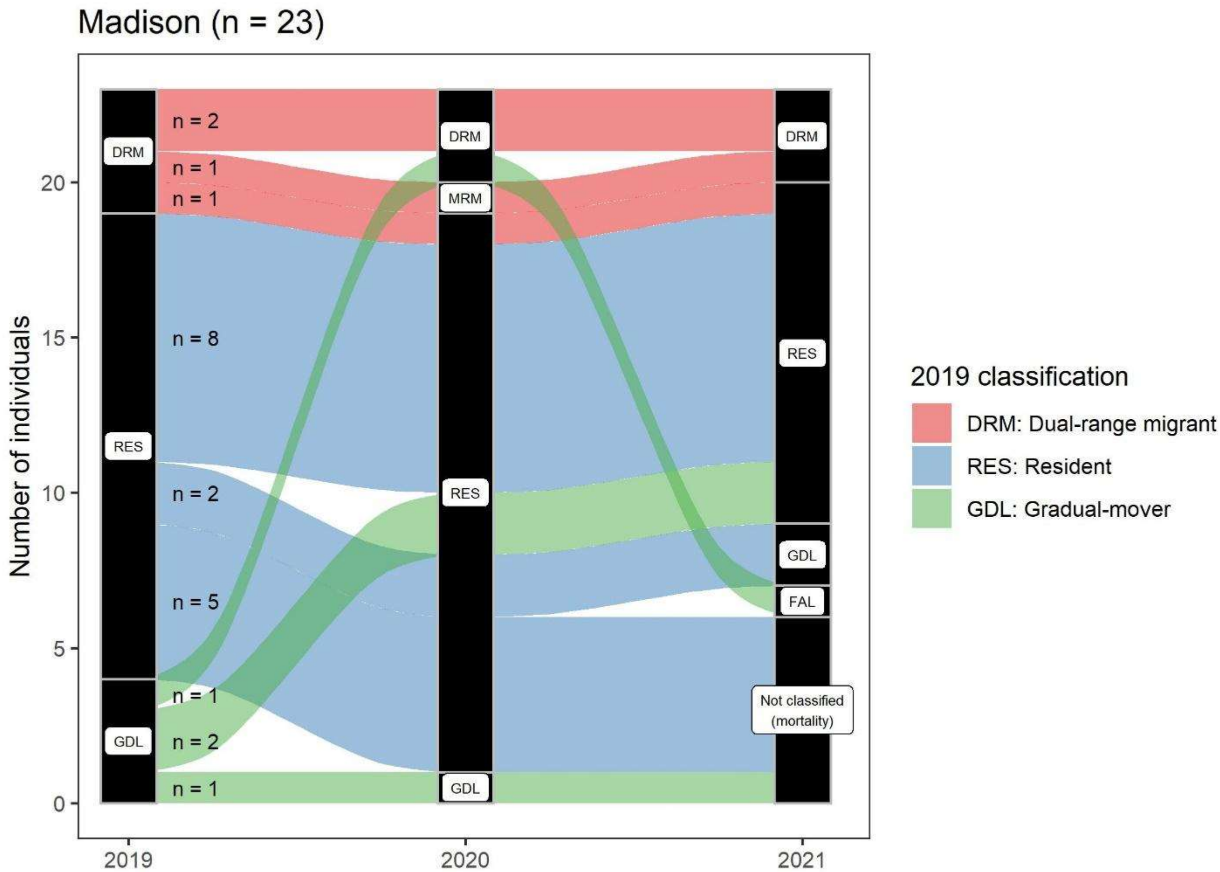


Figure 40. Number of migratory strategy classification switches between the 2019, 2020, and 2021 years for pronghorn captured in the Madison study areas between 2019 and 2021 in Montana, USA. Sample size (n) includes only individuals with ≥ 2 years of migratory strategy classifications.

Figure 41. Number of migratory strategy classification switches between the 2020 and 2021 migratory years across all study areas of pronghorn captured between 2019 and 2021 in Montana, USA. Sample size (n) includes only individuals with 2 years of migratory strategy classifications.

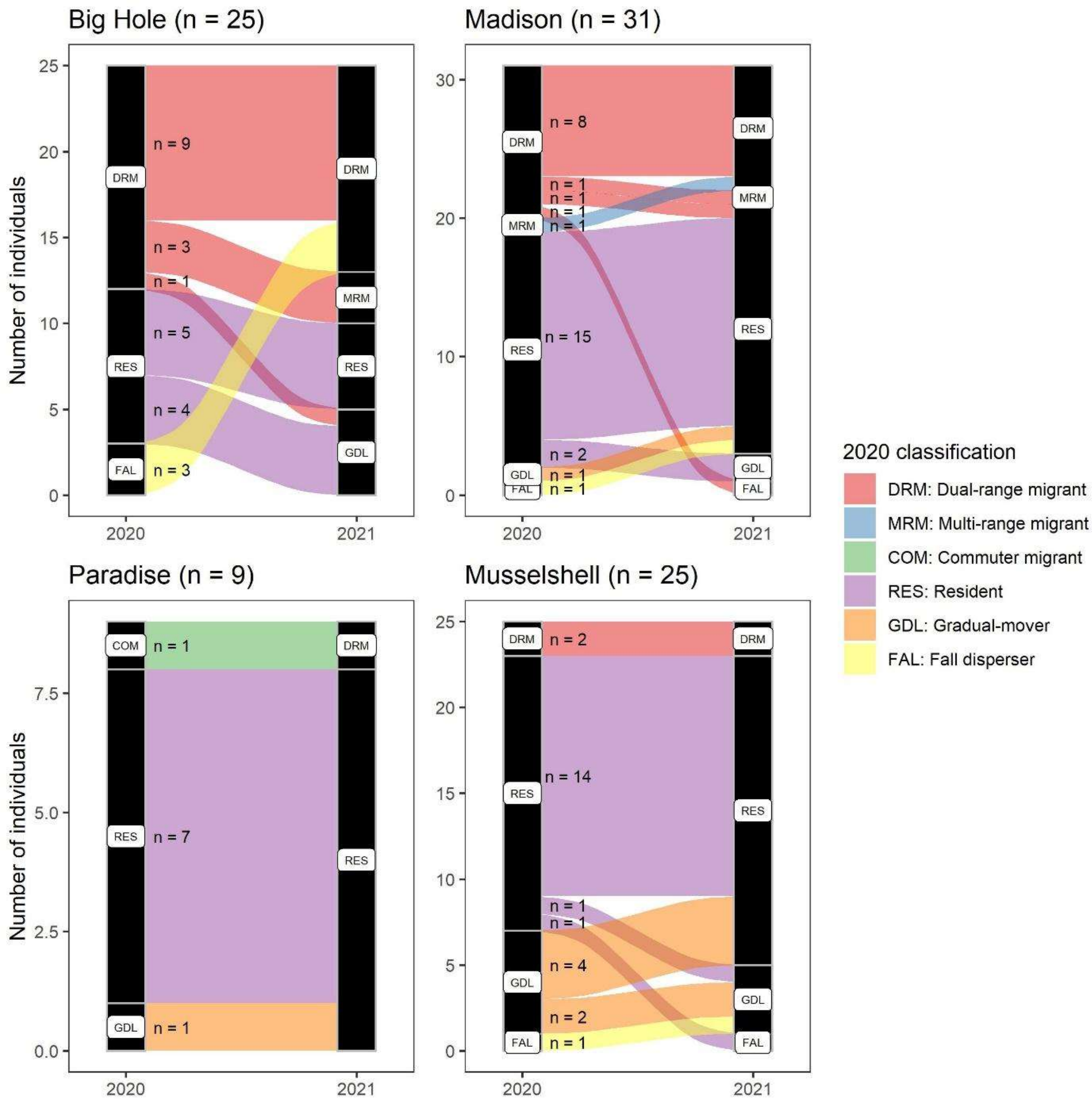


Figure 42. Number of migratory strategy classification switches between the 2020 and 2021 years for pronghorn captured in the Big Hole, Madison, Paradise, and Musselshell study areas between 2019 and 2021 in Montana, USA. Sample sizes (n) for each study area include only individuals with 2 years of migratory strategy classifications.

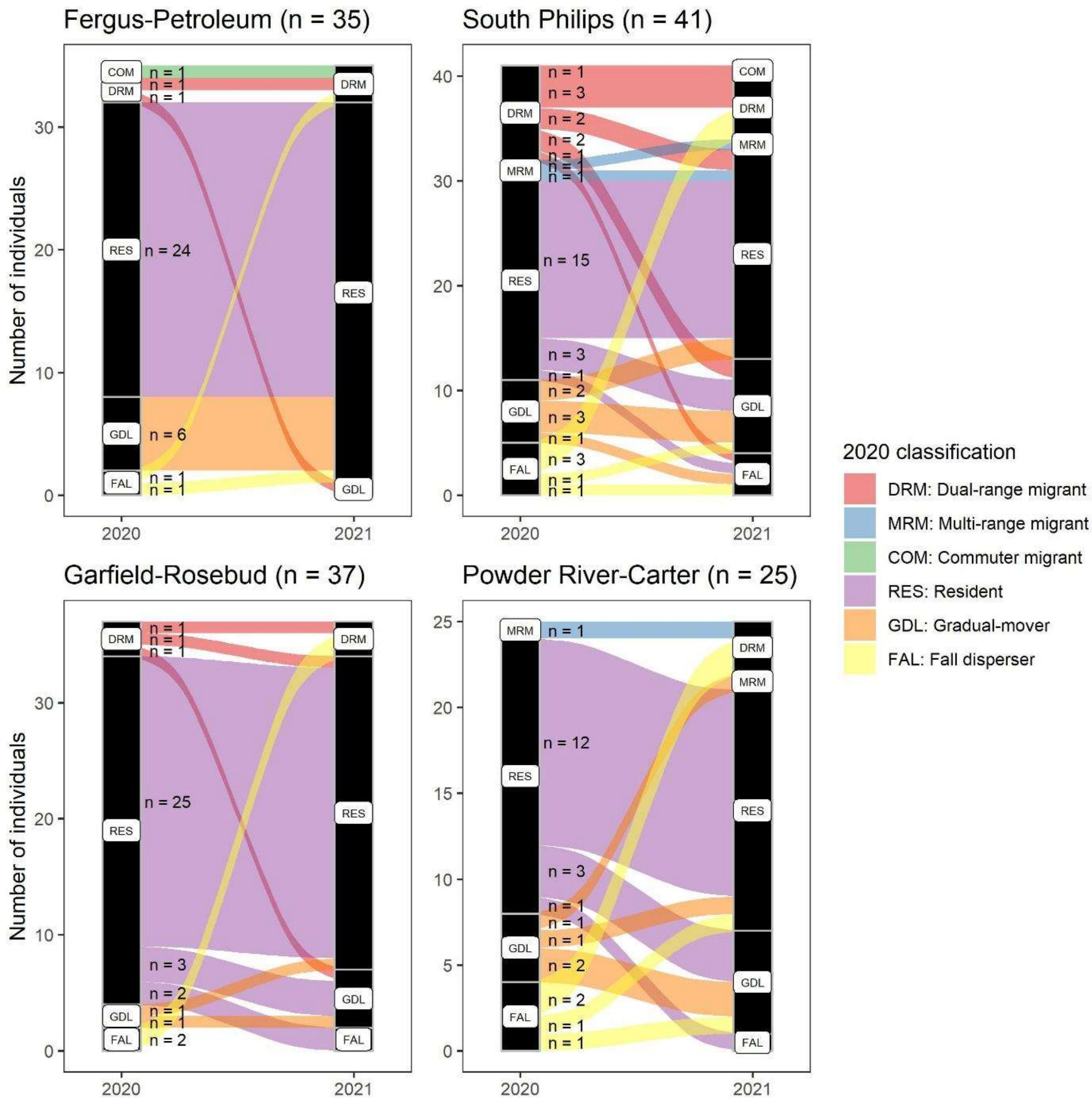
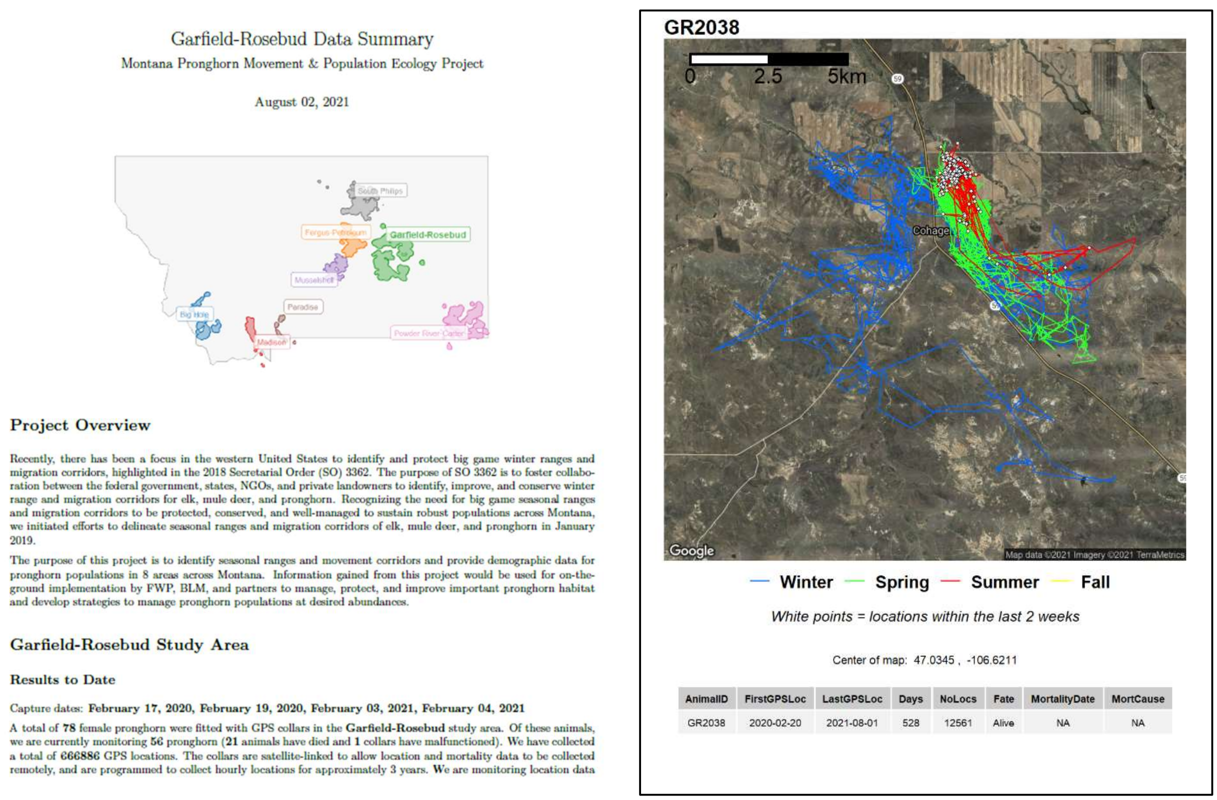


Figure 43. Number of migratory strategy classification switches between the 2020 and 2021 years for pronghorn captured in the Fergus-Petroleum, South Philips, Garfield-Rosebud, and Powder River-Carter study areas between 2019 and 2021 in Montana, USA. Sample sizes (n) for each study area include only individuals with 2 years of migratory strategy classifications.

Objective #2: Distribute maps of seasonal range and movement areas for pronghorn widely to conservation partners and landowners via a web-based platform

2.1 Generation and distribution of maps

Since the initiation of the location data collection, we have generated monthly summary reports of animal distributions and movements specific to each study area (Figure 44). These reports include population- and individual-level maps, with individual-level maps showing seasonal movements. On a monthly basis, we distribute these reports to state and federal agency biologists, non-profit conservation organizations, and private landowners. We generate these reports in lieu of a web-based platform but do make location data available to FWP and BLM wildlife staff associated with each study area on the ArcGIS Online platform (see Section 3.1). All animal movement data sharing associated with this project is aligned with FWP policy and directions for data sharing.



Garfield-Rosebud Data Summary

Montana Pronghorn Movement & Population Ecology Project

August 02, 2021

Project Overview

Recently, there has been a focus in the western United States to identify and protect big game winter ranges and migration corridors, highlighted in the 2018 Secretarial Order (SO) 3362. The purpose of SO 3362 is to foster collaboration between the federal government, states, NGOs, and private landowners to identify, improve, and conserve winter range and migration corridors for elk, mule deer, and pronghorn. Recognizing the need for big game seasonal ranges and migration corridors to be protected, conserved, and well-managed to sustain robust populations across Montana, we initiated efforts to delineate seasonal ranges and migration corridors of elk, mule deer, and pronghorn in January 2019.

The purpose of this project is to identify seasonal ranges and movement corridors and provide demographic data for pronghorn populations in 8 areas across Montana. Information gained from this project would be used for on-the-ground implementation by FWP, BLM, and partners to manage, protect, and improve important pronghorn habitat and develop strategies to manage pronghorn populations at desired abundances.

Garfield-Rosebud Study Area

Results to Date

Capture dates: **February 17, 2020, February 19, 2020, February 03, 2021, February 04, 2021**

A total of **78** female pronghorn were fitted with GPS collars in the **Garfield-Rosebud** study area. Of these animals, we are currently monitoring **56** pronghorn (**21** animals have died and **1** collars have malfunctioned). We have collected a total of **666886** GPS locations. The collars are satellite-linked to allow location and mortality data to be collected remotely, and are programmed to collect hourly locations for approximately 3 years. We are monitoring location data

AnimalID	FirstGPSLoc	LastGPSLoc	Days	NoLocs	Fate	MortalityDate	MortCause
GR2038	2020-02-20	2021-08-01	528	12561	Alive	NA	NA

Figure 44. Example pages from the Garfield-Rosebud monthly summary report generated for distribution to agency biologists and collaborators. Reports are updated and distributed monthly for each of the 8 study areas of the Montana Pronghorn Movement and Population Ecology Project.

Objective #3: Use seasonal range and movement data to identify potential barriers to movements, inform management decisions, and prioritize locations for habitat improvement projects

3.1 Identification of potential barriers to movements

The monthly reports summarizing pronghorn movement information (Section 2.1) have been used by area biologists to identify movement barriers and prioritize fence removal and modification projects for improving landscape permeability for pronghorn. Some projects are in progress or scheduled for completion within the next year (see Section 3.3). To facilitate the identification of potential barriers to pronghorn movements, we have developed three tools, including 1) an online platform based in ArcGIS Online for visualizing pronghorn movements and recording information on potential barriers as needed; 2) an online platform based in ArcGIS Online for mapping fences and recording fence attributes; and 3) interactive maps that display fences ranked by relative frequencies of altered behavioral responses to mapped fences. We discuss each of these products below.

3.1.1 ArcGIS Online: Pronghorn Movements and Barriers

The ArcGIS Online platform for visualizing pronghorn movements and recording information on potential barriers allows FWP biologists to access the collar movement data that is updated on a monthly basis (Figure 45). While the movement data can be displayed via the collar manufacturers website, our online platform provides easier access and ability to display the data for unique individuals that is clipped to capture and mortality dates. The platform also allows FWP biologists to identify and draw potential movement barriers that can be used for identifying or prioritizing remediation efforts.

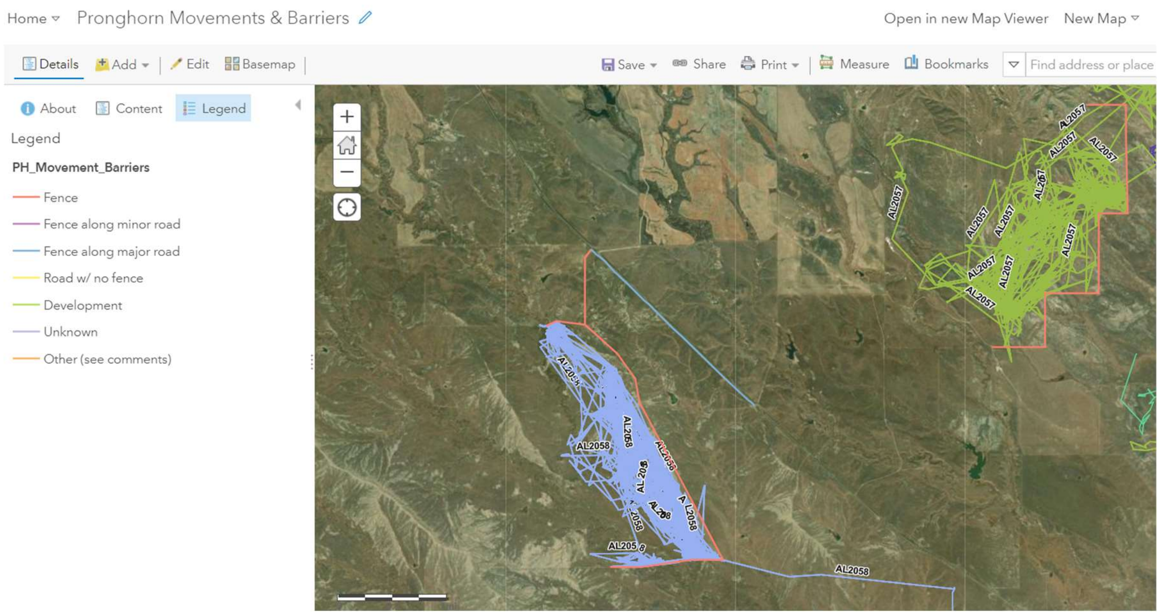


Figure 45. Example of potential movement barriers (orange and light blue lines) identified from adult female pronghorn collar location data (lines colored and labeled by individual) using the online platform on ArcGIS Online as part of the Montana Pronghorn Movement and Population Ecology Project.

3.1.2 ArcGIS Online: Montana Fence Mapping

The ArcGIS Online platform for fence mapping is a collaboration between FWP, the BLM (Montana/Dakotas) State-wide Wildlife Program, and University of Montana that was initiated summer 2021 to collect and aggregate spatial fence data (Figure 46). Accurate spatial data and attribute information for fences provides critical information for management and conservation of pronghorn and other important species, such as sage grouse; however, such information is lacking for the vast majority of Montana. The overall objective of the fence mapping project is to collect and aggregate spatially precise fence locations into a centralized database that could be updated and accessed simultaneously by multiple users for research and conservation applications. To accomplish this, we developed an ArcGIS Online web map which provides a platform for adding fence and attribute data to a line feature layer, as well as other point location information, such as gates or pronghorn crossings, to a point feature layer. This information can be added by drawing fences in the office based on aerial maps and in the field using tablets. When in the field, users can add attributes to mapped fences, verify and move positions of mapped fences, and map any additional fences. Recently, we created a new ArcGIS Online group that permits BLM staff to collaborate on these same, centralized data. The original intent of the project was to map fences in each of the 8 pronghorn study areas (represented by annual ranges from the GPS collared pronghorn); however, given expressed interest and need by BLM, data is currently being collected by BLM staff at a broader scale outside the study areas.

Fences are added to the fence data feature layer such that each line is mapped as spatially precise as possible, either drawn from aerial imagery base maps in the office or from GPS equipped handheld computers in the field. Each line feature is drawn to represent a segment of fence (e.g., a stretch of fence between corner fence posts, fence intersections, or substantial directional changes in the overall fence) that should have all the same characteristics (wire type, height, etc.). Upon visitation in the field, attributes can then be added to each line feature, or the line feature can be relocated to a more precise location if needed. Our protocol for field visitation includes recording the primary and bottom wire type, number of total strands, and bottom and top wire height. The wire height attributes are calculated from the average distance from the ground to the lowest wire based on at least 5 measurements along the fence segment, making each measurement at every 3rd midpoint (middle location of each post-to-post section) and trying to ensure the measurements are as representative of the entire fence segment as possible. Visited line features are then marked as field verified.

To date, we have mapped a total of 52,476 fence segments, with 622 verified in the field, equating to approximately 32,608 km and 691 km of total and field verified fences, respectively. Of the field verified fences classified as barbed primary wire type, we have recorded approximately 39 km of smooth bottom strand and 403 km of barbed bottom strand fences (with varying number of strands). We have recorded 87 km of woven primary wire type fences.

Using this fence mapping data in combination with location data from collared pronghorn, we used methods developed by Xu et al. (2021*b*) to produce a tool that ranks and maps fences based on relative levels of altered fence encounters of pronghorn (Section 3.1.3). In addition, we have evaluated the effects of different fence types on pronghorn movement behaviors (DeVoe et al. *in press*; Section 3.2). Technicians are expected to complete mapping of non-field verified fences using aerial imagery within the pronghorn annual ranges by the end of fall 2022.

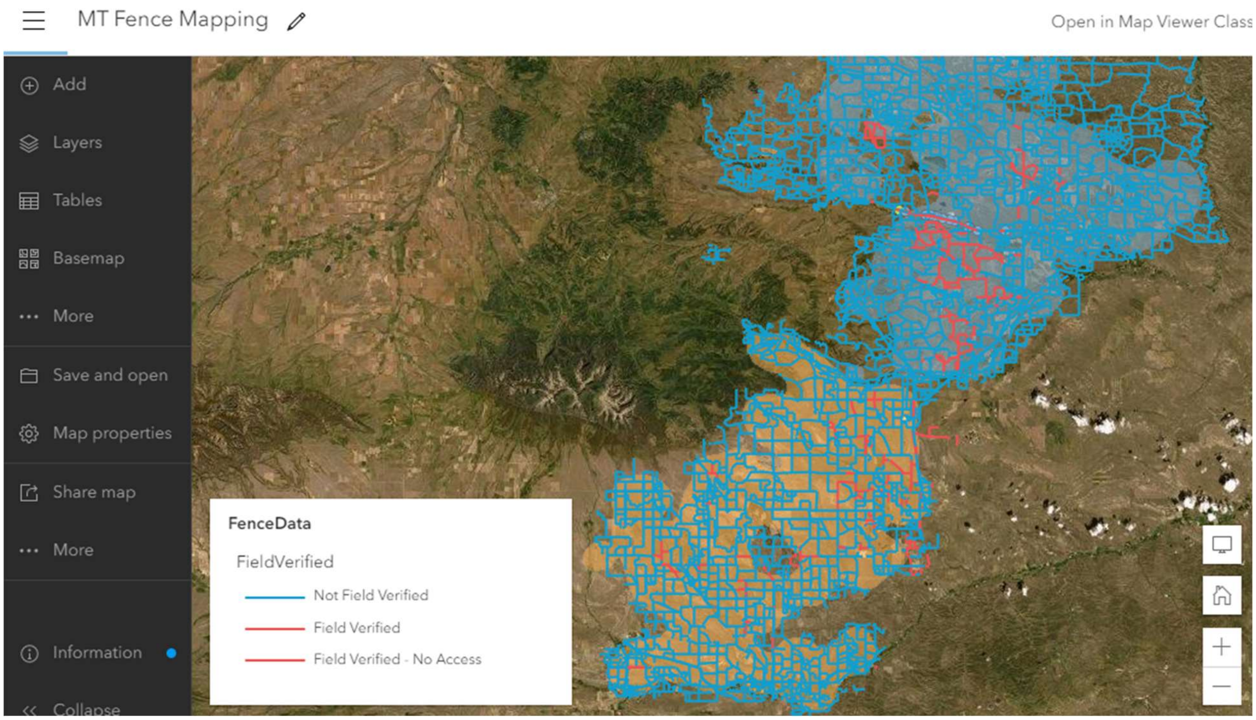


Figure 46. Example of fence spatial data recorded in the field within annual ranges of each population using the online platform on ArcGIS Online as part of the Montana Pronghorn Movement and Population Ecology Project. Red and blue lines represent mapped fences with and without fence characteristics measured in the field, respectively.

3.1.3 Fence Rankings Interactive Mapping

The interactive map for displaying fences ranked by pronghorn behavioral responses combines the fence data collected from the ArcGIS Online platform and the collar location data to provide an additional tool to identify, prioritize, and monitor fence modifications. While the methods have not been finalized, the tool uses the Barrier Behavior Analysis (Xu et al. 2021*b*) to categorize pronghorn responses to fence segments into six behavioral types, including quick cross, average movement, bounce, back and forth, trace, and trapped (Figure 47). These behavioral types are then classified into unaltered (i.e., quick cross and average movement) and altered (i.e., bounce, back and forth, trace, and trapped) encounter types, and the fence segments are ranked based on the ratio of altered to unaltered movements weighted by the number of unique animals encountering the fence segment (Figure 48). It is important to note that although the rankings will be adjusted based on the number of unique animals encountering the fence segments, the rankings will be sensitive to the distribution of collared pronghorn in the area. Therefore, caution must be used when interpreting the results from this tool and we suggest its use to be in combination with other information and resources to guide prioritization of projects. We will continue to work on this tool to output maps for each study area as additional movement and fence data become available.

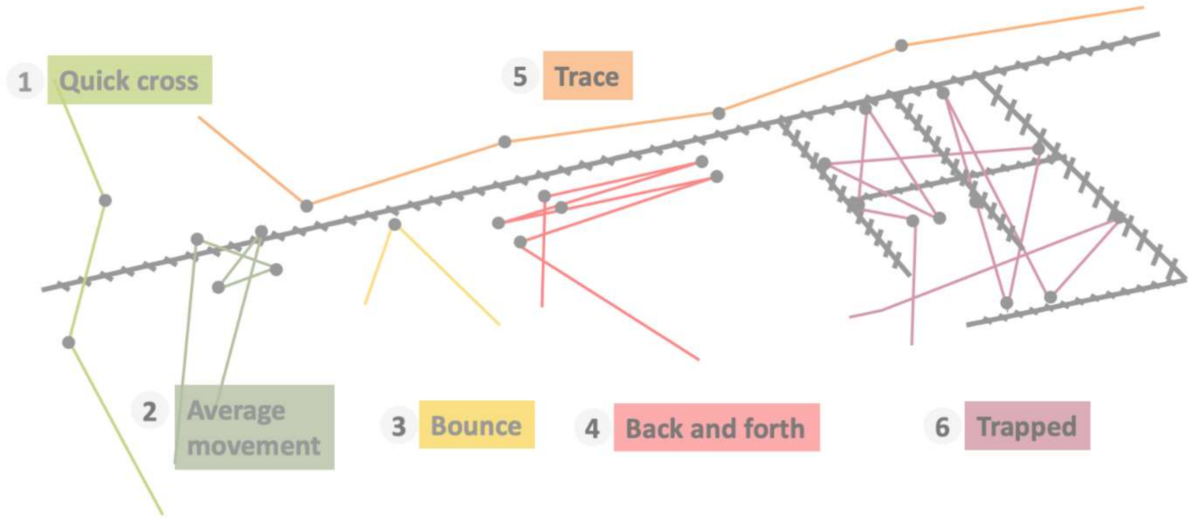


Figure 47. Schematic diagram reproduced from Xu et al. (2021) showing the six behavioral types identified in the Barrier Behavioral Analysis. Behavioral types are then classified into unaltered (i.e., quick cross and average movement) and altered (i.e., bounce, back and forth, trace, and trapped) to calculate fence segment rankings.

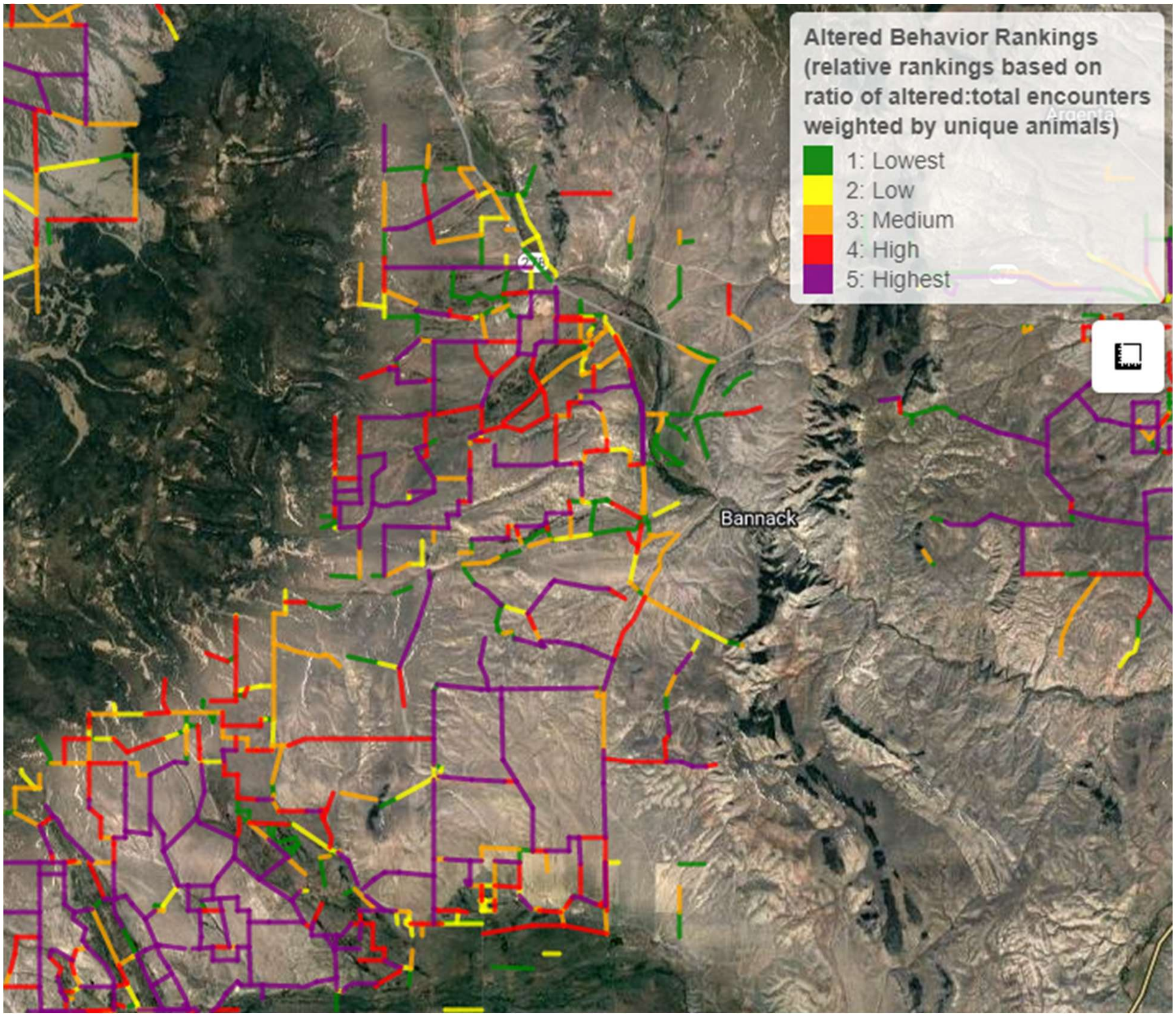


Figure 48. Screenshot of interactive map displaying mapped fences ranked by levels of altered movements of collared pronghorn. Methods for this analysis are currently in development and have not been finalized.

3.2 Evaluating the effect of varying fence types on pronghorn movements behaviors

In addition to the tools designed to assist in identifying potential barriers to pronghorn movements, we completed an analysis that combines the collar and fence data to evaluate the effect of different fence types on pronghorn movement behaviors. This analysis has been accepted as a research article in the peer-review journal Ecosphere and is currently in press (DeVoe, J, K Proffitt, and J Millspaugh. *Fence types influence pronghorn movement responses.* Ecosphere.). Understanding pronghorn movement responses to fences is essential for improving landscape permeability; however, prior studies provide only limited insight due to lack of information on fence characteristics and small sample sizes. This analysis used the hourly collar locations in six of the study areas (Madison, Musselshell, Fergus-Petroleum, South Philips, Garfield-Rosebud, and Powder River-Carter) and identified encounters with the mapped fences based on Xu et al. (2021b) to evaluate three movement responses (i.e., probability of an unaltered initial response, probability of crossing following an altered initial response, and passage time following an altered initial response) as a function of fence and landscape attributes. We combined our fence mapping data with fence data collected prior to the study in FWP Regions 6 and 7, and classified fences into three types, including low strand (average lowest wire height < 41 cm), high strand (average lowest wire height ≥ 41 cm), and woven wire. Based on 5,581 encounters identified from movement pathways of 265 collared pronghorn and 979 km of mapped fences, we found that variability in pronghorn fence response was correlated with fence type (Figure 49). Woven wire fences substantially reduced unaltered initial and crossing responses and increased passage times as compared to low (i.e., average lowest wire height < 41 cm) or high (i.e., average lowest wire height ≥ 41 cm) strand fences. Both low and high strand fences elicited similar responses of being relatively permeable at the initial encounter with reduced permeability thereafter. Fence crossing probabilities following altered initial responses increased through time modestly for strand fences but only negligibly for woven wire fences, with passage times averaging approximately fourteen hours. Pronghorn knowledge of and fidelity to specific permeable locations along fences, which may be due to inconsistent fence and landscape characteristics along the fence stretch, likely allow some woven wire fences and most strand fences, regardless of the average lowest wire height, to be permeable. To improve landscape permeability, these results indicate that managers should prioritize removing woven wire fences, replacing woven wire fences with strand fences, and incorporating variation in lowest wire heights into new fence designs or modifications of existing fences.

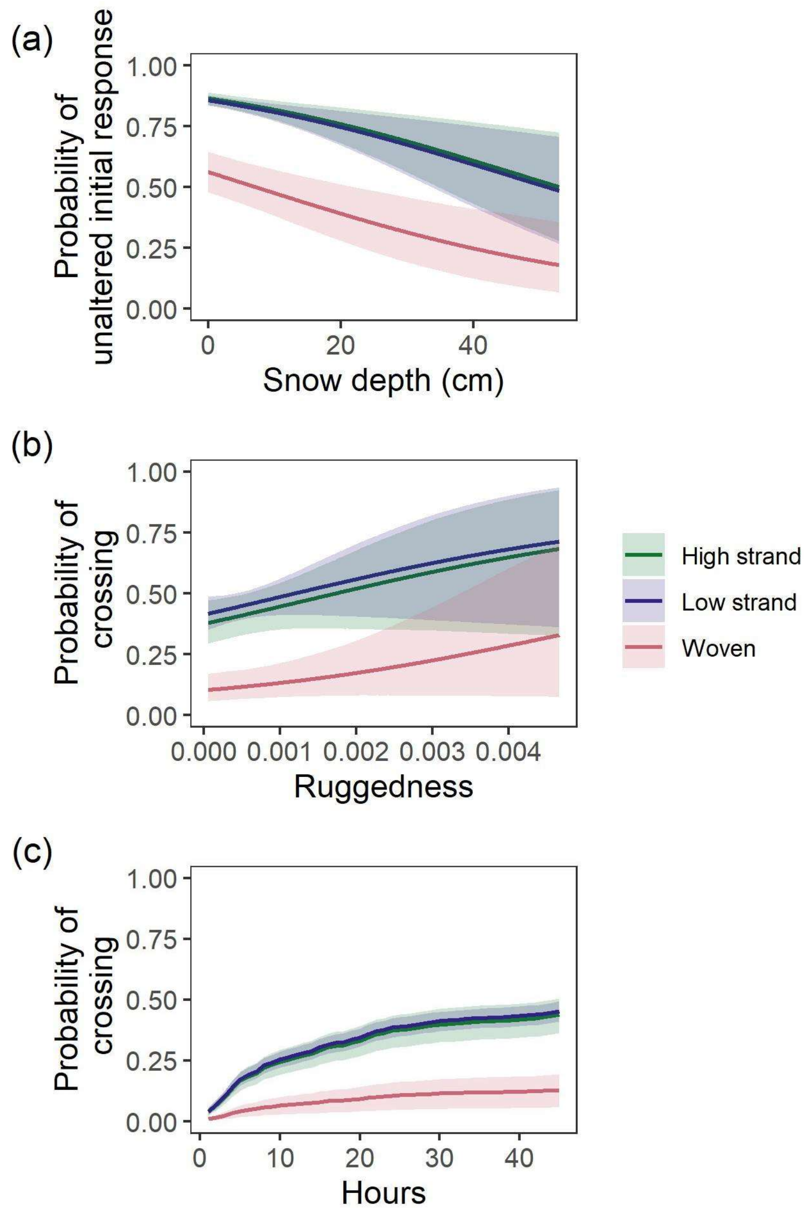


Figure 49. Predicted relationships of the probability (± 95% CI) of unaltered initial response (panel a), probability of crossing following an altered initial response (panel b), and passage time (i.e., probability of crossing through time) following an altered initial response (panel c) of pronghorn fence encounters for different fence types in 6 study areas in southwest, central, and southeast Montana, 2019 – 2021. Displayed relationships are based on averaged top models from each respective analysis and contain the range of the observed covariate values while keeping all other covariates constant at their mean value. Low and high strand fences are defined as wire fences with lowest wire height < 41 cm and ≥ 41 cm, respectively.

3.3 Efforts to remediate movement barriers

Biologists from multiple organizations have been using and continue to use the collar movement information to inform efforts to remediate movement barriers, which have primarily included fence removals and replacements with wildlife friendly designs (Figure 50 and 51; Table 5). In total, 12 projects have been completed (totaling 23 miles), 6 are ongoing (totaling 33 miles), and 3 are in preparation (totaling 10 miles).

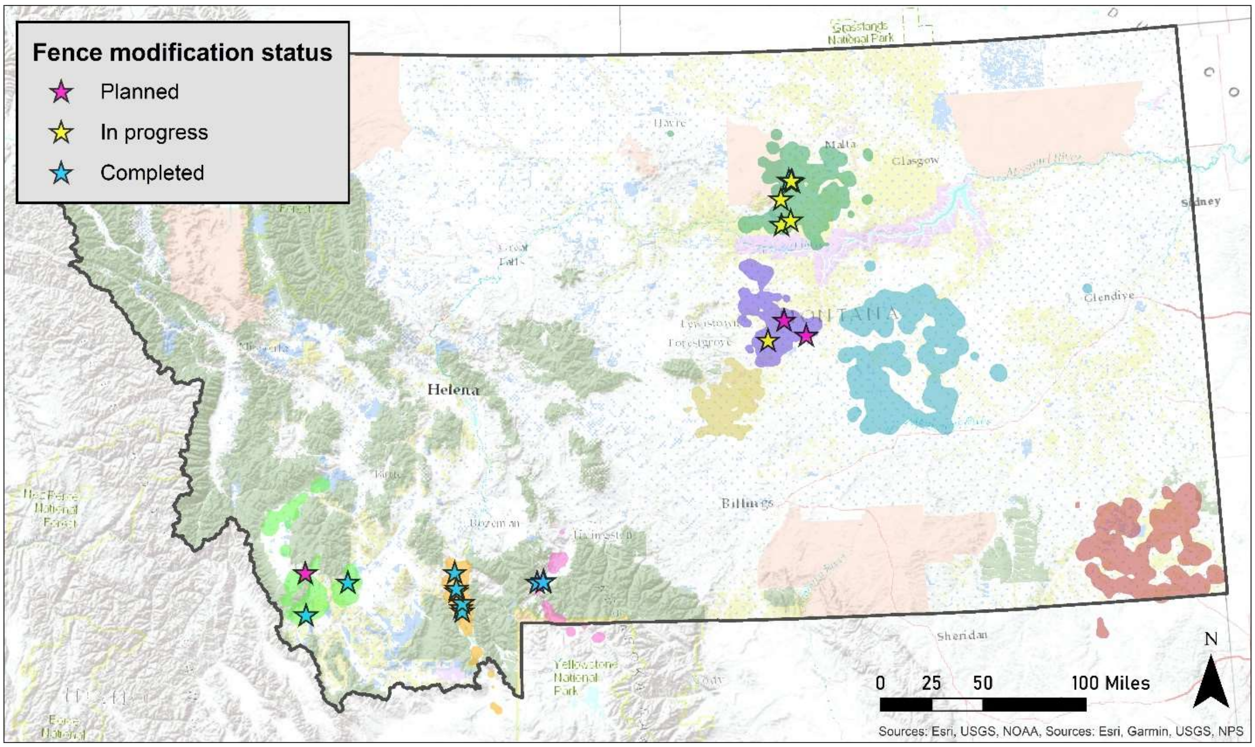


Figure 50. Locations of planned, in progress, and completed fence modification efforts informed by the pronghorn collar movement data collected as part of the Montana Pronghorn Movement and Population Ecology Project

Figure 51. Examples of fence modification projects informed by the pronghorn collar data and completed by partners of the Montana Pronghorn Movement and Population Ecology Project. Top left photo: modifying a 5-strand fence to a 4-strand fence with smooth bottom wire in the Paradise study area (photo credit: National Parks Conservation Association). Top right photo: new 4-strand fence with smooth bottom wire replacing 5-strand barbed wire fencing in the Fergus-Petroleum study area (photo credit: BLM). Middle photo: installing metal panels to replace 5-strand barbed wire fence in the Paradise study area (photo credit: National Parks Conservation Association). Bottom left image: signage used for outreach in the Madison study area. Bottom right photo: removing barbed bottom wires in the South Philips study area (photo credit: BLM).

Table 5. List of completed, ongoing, and planned remediation projects to improve landscape permeability for pronghorn initiated based on pronghorn collar data from the Montana Pronghorn Movement and Population Ecology Project.

Project name	General area	Status	Completion year	Type of modification (WF = wildlife friendly)	Length (mi)	Ownership	Lead agency*
Indian Creek	Madison Valley	Completed	2019	Old: jackleg w/ barbed New: post-and-wire WF	0.25	Private/BLM	BLM
Indian Creek	Madison Valley	Completed	2020	Old: jackleg w/ barbed New: post-and-wire WF	0.65	Private/State/ BLM	BLM
SW MT Fencing for Wildlife Program	Horse Prairie	Completed	2021	Old: 4-6 strand barbed/woven New: removed/modified to WF	8.5	Private/BLM	NWF
SW MT Fencing for Wildlife Program	Frying Pan Basin	Completed	2021	Old: 4-6-strand barbed/woven New: removed/modified to WF	3.4	Private/BLM	NWF
Creek Bottom Project	SW of Malta	Completed	2021	Old: 4-strand barbed New: 4-strand barbed WF	2.33	Private	RSA
GYCC West Creek/Mountain Sky	Paradise Valley	Completed	2022	Old: 5-strand barbed New: 4-strand WF	0.2	Private	NPCA
GYCC Big Creek	Paradise Valley	Completed	2022	Old: 5-strand barbed New: 4-strand WF w/ wildlife passage post-rail section.	0.3	Private	NPCA
GYCC Antelope Basin	Paradise Valley	Completed	2022	Old: 5-strand barbed New: WF panel configuration	0.2	Private	NPCA
Black Mountain Ranch	Madison Valley	Completed	2020	Old: 5-strand barbed New: 4-strand WF suspension fence	2.5	Private	NPCA
Granger Ranches	Madison Valley	Completed	2020	Old: 5-strand barbed New: 4-strand WF suspension fence	2.5	Private	NPCA
Goggins N. Ennis	Madison Valley	Completed	2021	Old: 5-strand barbed New: 3-strand high tensile, electr. lay-down	1.3	Private	NPCA
Granger Ranches	Madison Valley	Completed	2021	Old: 5-strand barbed New: 4-strand WF suspension fence	1	Private	NPCA
BLM Malta Field Office 2021 MCC Project	Dry Fork Rd South Phillips	In progress	2022	Removal of bottom strands	4.5	BLM	BLM
Outcome Based Grazing Fence Mods Phase 1	SW of Winnett	In progress	2022	Old: 5-strand barbed New: 4-strand WF	2.5	Private/BLM	BLM
Marks Individual Fence Mods Phase 1	N of Winnett	Planned	2022	Old: 5-strand barbed New: 4-strand WF	2	BLM	BLM
RCPP Fence	SE of Winnett	Planned	2022	Old: 5-strand barbed New: 4-strand WF	0.75	Private/BLM	BLM/ NRCS
South Phillips Project (LBWR)	SW of Malta	In progress	2023	Old: 4-strand barbed New: 4-strand barbed WF	9.42	Private	RSA

Project name	General area	Status	Completion year	Type of modification (WF = wildlife friendly)	Length (mi)	Ownership	Lead agency*
Turbine Project	SW of Malta	In progress	2023	Old: 4-strand barbed New: 4-strand barbed WF	2.25	Private	RSA
Chinook Winds Project	SW of Malta	In progress	2023	Old: woven New: 4-strand barbed WF	6	TNC	RSA
FlyBoy Project	SW of Malta	In progress	2023	Wire height adjusted to WF	8	Private	RSA
Carroll Hill	Big Hole	Planned	2023	Old: 5-strand barbed New: 4-strand WF	7.5	Private/USFS	NWF

**NWF = National Wildlife Federation, NPCA = National Parks Conservation Association, RSA = Rangeland Stewardship Alliance.*

Objective #4: Develop a population model to identify important vital rates affecting population growth rates and describe important demographic differences between populations that are growing or stable, versus those that are limited in their population performance

4.1 Integrated Population Model

Integrated population models (IPMs) can integrate known-fate survival from marked adults, recruitment and abundance data from count and classification surveys, and harvest data to provide estimates of vital rates and improve inferences into the underlying driers of variation of these vital rates (Kéry and Schaub 2011, Schaub and Abadi 2011). Management decisions can be improved by the use of IPMs in several ways that include: sensitivity and elasticity analyses for determining the vital rate most important in driving population abundance and targeting management actions specific to that vital rate (Johnson et al. 2010*a*, Eacker et al. 2017); retrospective analyses for estimating vital rates (Proffitt et al. 2021) and population abundances and assessing the factors influencing annual variability in vital rates (Paterson et al. 2021); and prospective analyses for projecting population abundances under different management scenarios under consideration (e.g., what harvest rates increase or decrease populations by how much and over what amount of time; Johnson et al. 2010*b*, Mitchell et al. 2018). Integrated population models, therefore, can be a powerful learning tool that may help resource managers to understand the mechanisms driving population performance and to adapt management strategies accordingly.

Our objective is to develop a pronghorn IPM based on abundance and production estimates from count and ratio surveys and harvest data collected for each study area (Figure 52). We will be using a state-space IPM approach, wherein the model consists of a biological process model and an observation model (see Section 4.2; Buckland et al. 2004). We will use this model to 1) identify important vital rates affecting population growth rate, 2) contrast important vital rates between populations that are increasing and decreasing at different rates, and 3) develop hypotheses to explain why some pronghorn populations experience limitations on population growth rate. The population model will provide information towards developing more focused investigations into ecological and/or anthropogenic factors influencing pronghorn populations in Montana.

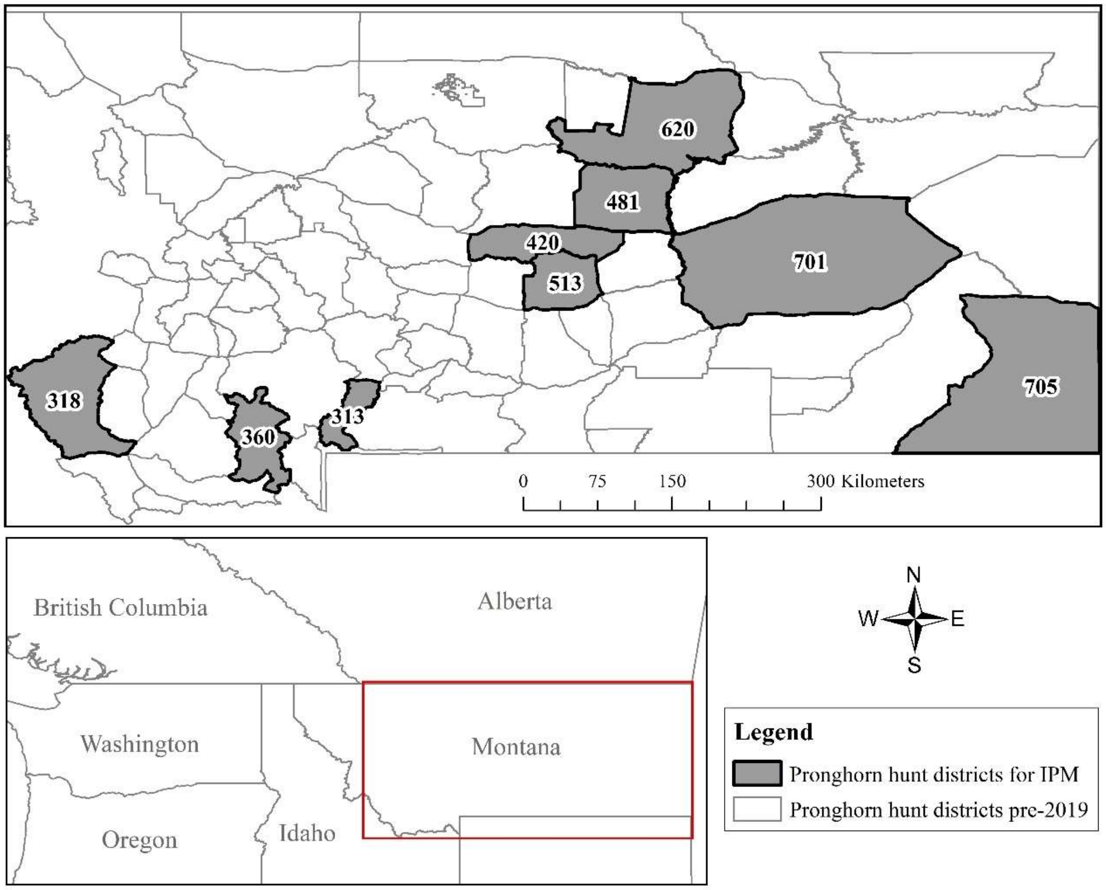


Figure 52. The nine pronghorn hunting districts (shaded gray) within the pronghorn study areas included in the integrated population model for the Pronghorn Movement and Population Ecology Project.

We have begun model development. As Bayesian modeling techniques permit the incorporation of prior information, we summarized pronghorn vital rate literature values to create informative priors for our models. These derived estimates will be included as prior values of pronghorn vital rates in our recruitment and survival models.

We defined a pronghorn ecological year from 1 October of year t-1 to 30 September of year t to account for post-parturition count and age-sex ratio surveys in July, and the timing of population reconstruction estimates immediately prior to October harvest. We chose to use the beginning of the antelope rifle season as our model anniversary because we assume most animals are harvested with rifles, and thus archery mortality is relatively minimal. Pronghorn age classes are defined as fawn: 0–3 months, juvenile: 3–15 months, and adult: 15+ months. Fawns advance to the juvenile age class in September of their first year, prior to hunting season. Therefore, a fawn cannot be harvested, but could be harvested as a juvenile. This designation aligns with the way in which MFWP stores fall harvest data (two stages, two sexes).

The biological process model is a discrete time (i.e., 1 October of year t-1 to 30 September of year t), three-stage (i.e., fawn, juvenile, adult) and two-sex (i.e., male, female) matrix projection model. Recruitment will be modeled following the methods presented by White and Lubow (2002). We assume that fawns are recruited into the juvenile age class in September at a rate similar to the age-sex counts observed during July aerial surveys. We further assume that the sex ratio at birth is equal. In this manner, we are able to use the fawn:doe ratio data collected during summer aerial surveys as a measure of reproductive output (i.e., recruitment), which better aligns the biological process with data collection.

In our juvenile and adult survival process models, we will broadly compartmentalize mortality into harvest and natural mortality through a multi-state survival model. A multi-state survival model will allow estimation of survival (S), harvest mortality (H), and other mortality (O), where $S + H + O = 1$. In this framework, survival estimates reflect survival from both harvest as well as natural causes of death.

Our recruitment and survival process models will examine environmental variables thought to affect pronghorn population vital rates. To account for potential lag-effects on survival and recruitment, we will examine vegetation and climatic conditions from both the current and previous model year (Figure 53). We have established hypotheses and predictions related to biological processes in our recruitment and survival models.

We hypothesize that annual variation in fawn recruitment may be driven by maternal body condition during gestation, through fat accumulation and subsequent fat loss in the summer and winter season prior to parturition (Garrott et al. 2003, Cook et al. 2004, Hurley et al. 2014, Paterson et al. 2019). In addition, recruitment may be affected by environmental conditions post-parturition that affect fawn nutrition through maternal provisioning or forage productivity (Beale and Smith 1970, Von Gunten 1978, Griffin et al. 2011, Bender et al. 2013).

We hypothesize that annual variation in juvenile and adult survival may be driven by body condition throughout the ecological year via the additive effects of accumulated fall fat reserves, subsequent winter fat loss (Cook et al. 1996, 2004, Garrott et al. 2003, Reinking et al. 2018), and fat accumulation in the following growing season (Miller and Drake 2003, O'Gara 2004*b*). In addition, juvenile and adult survival may be driven by harvest rate (Jacques et al. 2007, Kolar et al. 2012).

Currently, we are considering relevant environmental covariates at the hunting district scale to include in our survival and recruitment models. Spatially aligning count and covariate data to the hunting district level will provide demographic information at the scale in which harvest regulations are developed. The covariates included in our process models will be used as indices for forage productivity, summer environmental conditions across the growing season, and winter severity. Thus, we predict that greater forage productivity and favorable summer conditions will have a positive effect on survival and recruitment, whereas winter severity will have a negative effect on survival and recruitment.

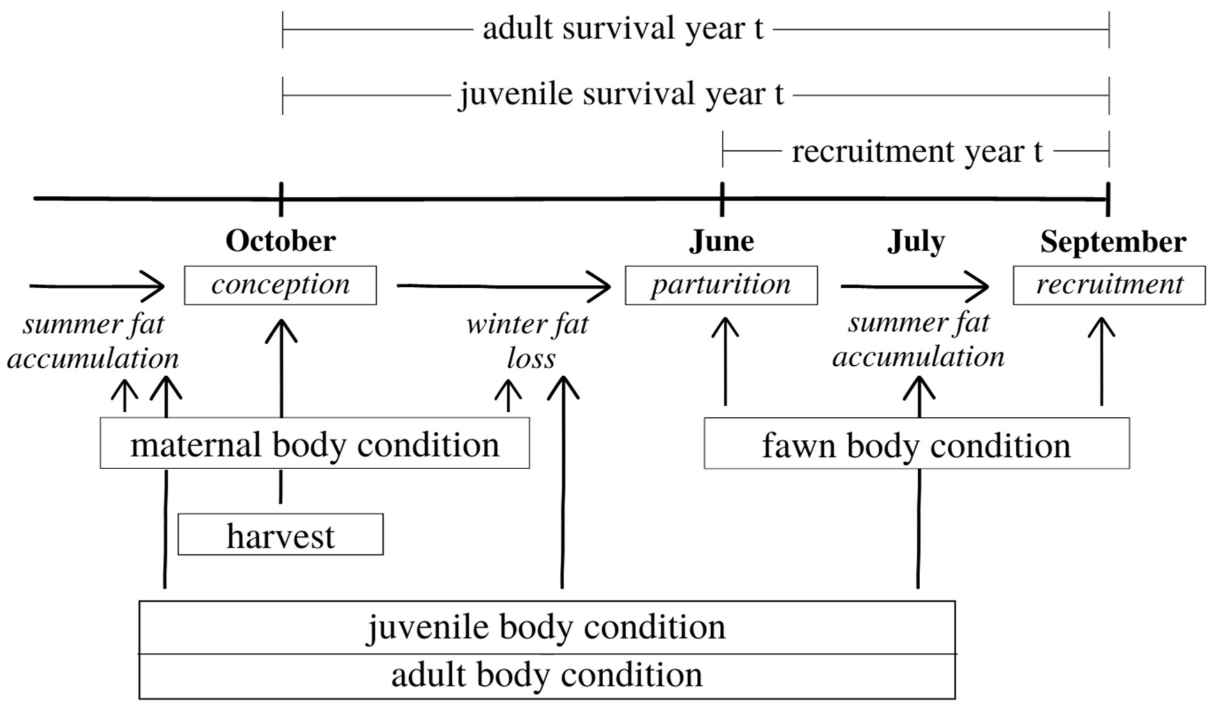


Figure 53. Concept diagram explaining the ecological year experienced by pronghorn and associated covariates in our survival and recruitment process models. Model year is 1 October year t-1 to 30 September year t, where fawn and adult count and ratio surveys occur in July after parturition, and adult and juvenile harvest occurs in October. Age classes are defined as fawn: 0–3 months, juvenile: 3–15 months, and adult: 15+ months. Fawn recruitment into the population is affected by maternal body condition during gestation and fawn body condition post-parturition. Juvenile and adult survival are affected by body condition throughout the model year and harvest.

4.2 Observation Model

Observation models link empirical field data to biological parameters in the model (Schaub and Abadi 2011). For example, count and harvest data are used in the observation model to define survival. Survival is also defined in the biological process model, thus establishing the link between the process model and observation model.

Pronghorn count data are collected during surveys that occur at two times of year and in two different structures (Table 6). The first type of count data is a total count, collected through complete coverage surveys or trend extrapolated surveys. While complete coverage surveys aim to count and classify all antelope in the hunting district (HD), trend surveys count and classify only those antelope within trend area(s). Trend areas in each hunting district were selected based on the 1-3 subunit(s) whose population trends were most representative of the total population, wherein trend area counts can be used to accurately predict the total population. Mean pronghorn density from trend areas is extrapolated to the HD level using the area of pronghorn habitat delineated by the MFWP pronghorn habitat layer. Further details can be found in the MFWP evaluation of survey protocols report (Newell 2013). Total counts (both complete coverage and trend extrapolated) will be treated as true abundance estimates, thus the observation model for total counts will be a normal distribution, which assumes that counts are equally likely to be under- or over-estimates of true abundance.

Total counts occur in both the summer and winter seasons, depending on the hunting district region (Table 6). Winter counts will be adjusted to align with the model anniversary (October 1). The adjustment will include adding harvested animals to the counts and removing natural mortality. For winter count data, estimated abundance will be defined at the model anniversary as a function of the winter count plus the estimate of harvest, divided by the survival rate for the period of time between the model anniversary in October and the winter count conducted in April. As the survival rate is assumed to be an annual (12 month) rate, survival is discounted to the 7-month rate to accommodate the difference between October and April.

The second type of data are stage and sex structured counts (Table 6), collected through summer age-sex ratio surveys. Structured counts will be used to inform the abundance of each age class in the observation model.

We will be using a novel approach that integrates harvest data, abundance estimates, and population reconstruction in an IPM framework. We will estimate abundance in the observation model by calculating the number of harvested animals divided by the harvest rate for each sex and age class. The harvest rate term used to reconstruct the population in the observation model is derived from the multi-state survival biological process model.

Once model covariates are determined, we will run the IPM for each hunting district and compare demographic parameter estimates across years both within and among study areas. In addition, we will examine which vital rates have the greatest effect on population growth rate for each hunting district study area. After working through these final stages of IPM development we envision rapid iteration and routine meetings to facilitate communication with field staff. The IPM will be developed and applied in the next reporting period.

Table 6. Pronghorn count data from 2007–2020, collected across 9 hunting distracts (HDs) in Montana. Pronghorn count data are collected during surveys that occur at two times of year: summer or winter. Total count surveys are further divided into two survey methods: complete coverage (CC) or trend extrapolated (TE) where surveys are conducted in specific trend areas. Additionally, stage and sex structured counts are collected during summer surveys in certain HDs.

HD	**Year**	**Survey Month**	**Survey Type**	**Trend Areas**	**Total**	**Bucks**	**Does**	**Fawns**	**Unk**
313	2007	March	CC	--	51	--	--	--	--
	2008	April	CC	--	71	--	--	--	--
	2009	May	CC	--	82	--	--	--	--
	2010	--	CC	--	58	--	--	--	--
	2011	May	CC	--	62	--	--	--	--
	2012	--	CC	--	95	--	--	--	--
	2013	--	CC	--	105	--	--	--	--
	2014	--	CC	--	121	--	--	--	--
	2015	--	CC	--	95	--	--	--	--
	2016	--	CC	--	112	--	--	--	--
	2017	July	CC	--	199	37	91	71	0
	2018	July	CC	--	99	33	53	13	0
	2019	July	CC	--	107	30	59	18	0
	2020	July	CC	--	71	12	50	9	0
318	2007	July	CC	--	1430	319	665	335	0
	2009	July	CC	--	1968	340	1072	555	0
	2011	July	CC	--	1027	178	528	201	0
	2013	July	CC	--	1466	229	771	321	0
	2015	July	CC	--	1758	374	834	510	0
	2017	July	CC	--	1490	340	797	353	0
	2019	July	CC	--	1141	246	631	232	0
360	2004	March	CC	--	2001	--	--	--	--
	2005	February	CC	--	2216	--	--	--	--
	2005	August	CC	--	1935	309	1091	533	2
	2007	April	CC	--	2146	--	--	--	--
	2008	April	CC	--	2210	--	--	--	--
	2009	April	CC	--	1899	--	--	--	--
	2009	July	CC	--	757	184	346	227	0
	2010	April	CC	--	1843	--	--	--	--
	2010	July	CC	--	1160	285	559	316	0
	2011	July	CC	--	1464	407	742	313	--
	2012	July	CC	--	900	274	416	195	15
	2013	March	CC	--	1715	--	--	--	--
	2013	July	CC	--	1331	195	770	354	12
	2014	April	CC	--	1610	--	--	--	--
	2014	July	CC	--	1280	371	547	339	23
	2015	April	CC	--	1556	--	--	--	--
	2015	August	CC	--	1435	331	718	368	18
	2016	March	CC	--	2480	--	--	--	--
	2016	July	CC	--	1166	245	610	291	20
	2017	February	CC	--	1959	--	--	--	--

HD	Year	Survey Month	Survey Type	Trend Areas	Total	Bucks	Does	Fawns	Unk
	2017	July	CC	--	1003	243	460	249	51
	2018	March	CC	--	1351	--	--	--	--
	2018	August	CC	--	1111	293	497	306	15
	2019	April	CC	--	1540	--	--	--	--
	2020	March	CC	--	1567	--	--	--	--
	2020	July	CC	--	471	96	248	127	0
420	2004	July	TE	Yellow Water Triangle	2323	587	1184	553	0
	2005	July	TE	Yellow Water Triangle	2566	555	1239	773	0
	2006	July	TE	Yellow Water Triangle	1666	398	796	472	0
	2007	July	TE	Yellow Water Triangle	2014	542	1137	335	0
	2008	June	TE	Yellow Water Triangle	1546	341	864	341	0
	2009	July	TE	Yellow Water Triangle	917	214	536	167	0
	2010	July	TE	Yellow Water Triangle	1165	294	678	193	0
	2012	July	TE	Yellow Water Triangle	716	142	423	150	0
	2013	July	TE	Yellow Water Triangle	608	127	345	136	0
	2014	July	TE	Yellow Water Triangle	686	136	354	195	0
	2015	July	TE	Yellow Water Triangle	1090	358	485	248	0
	2016	July	TE	Yellow Water Triangle	1006	299	462	241	0
	2017	July	TE	Yellow Water Triangle	1124	303	466	356	0
	2018	July	TE	Yellow Water Triangle	855	231	500	125	0
481	2004	July	TE	Warhorse	6177	1347	2816	2015	0
	2005	July	TE	Warhorse	6621	1539	2950	2132	0
	2006	July	TE	Warhorse	5178	1566	2137	1475	0
	2006	July	CC	--	7492	1611	3196	2385	0
	2007	July	TE	Warhorse	3238	748	1828	663	0
	2008	July	TE	Warhorse	3318	705	1806	705	0
	2010	July	TE	Warhorse	1341	289	898	155	0
	2010	July	CC	--	1760	371	1107	282	0
	2012	July	TE	Warhorse	786	80	545	160	0
	2013	July	TE	Warhorse	689	102	470	118	0
	2014	July	TE	Warhorse	1149	176	652	321	0
	2015	July	TE	Warhorse	1069	267	545	256	0
	2015	July	CC	--	965	174	525	266	0
	2016	July	TE	Warhorse	1405	342	657	406	0
	2017	July	TE	Warhorse	1133	171	604	358	0
	2017	July	CC	--	1351	265	642	444	0
	2018	July	TE	Warhorse	908	283	470	155	0
513	2004	July	TE	North	6898	1490	3060	2347	0
	2006	July	TE	North, South	4528	810	2120	1598	0
	2006	July	CC	--	4767	923	2255	1589	0
	2008	July	TE	North	4202	1110	2315	777	0
	2009	July	TE	North, North	5153	745	2854	1554	0
	2009	July	CC	--	2806	484	1612	710	0
	2010	July	TE	South	1742	266	1053	422	0
	2011	July	TE	North, South	1136	314	687	136	0
	2012	July	TE	North, South	996	127	619	250	0

HD	**Year**	**Survey Month**	**Survey Type**	**Trend Areas**	**Total**	**Bucks**	**Does**	**Fawns**	**Unk**
	2013	July	TE	North, South	1556	318	975	263	0
	2014	July	TE	North, South	1403	191	805	407	0
	2014	August	CC	--	1921	290	1082	549	0
	2015	July	TE	North, South	1848	276	911	661	0
	2016	July	TE	North, South	2251	509	1157	585	0
	2017	July	TE	North, South	2658	411	1255	992	0
	2018	July	TE	North, South	2132	699	1085	348	0
	2019	July	TE	North, South	2959	555	1441	962	0
	2020	July	TE	North, South	3464	907	1946	610	0
	2020	July	CC	--	4214	1090	2210	914	0
620	2004	July/August	TE	Count Unit 3, Count Unit 8	3106	602	1690	814	0
	2005	July/August	TE	Count Unit 3, Count Unit 8	6593	1239	3221	2133	0
	2006	July/August	TE	Count Unit 3, Count Unit 8	4478	1177	2124	1177	0
	2007	July/August	TE	Count Unit 3, Count Unit 8	9230	2478	4239	2513	0
	2008	July/August	TE	Count Unit 3, Count Unit 8	9142	2035	4655	2451	0
	2009	July/August	TE	Count Unit 3, Count Unit 8	7319	1761	3664	1894	0
	2010	July/August	TE	Count Unit 3, Count Unit 8	5487	1239	2655	1593	0
	2011	July/August	TE	Count Unit 3, Count Unit 8	2097	487	1221	389	0
	2012	July/August	TE	Count Unit 3, Count Unit 8	2150	451	1204	496	0
	2013	July/August	TE	Count Unit 3, Count Unit 8	1894	381	1062	451	0
	2014	July/August	TE	Count Unit 3, Count Unit 8	2938	611	1451	876	0
	2015	July/August	TE	Count Unit 3, Count Unit 8	3097	690	1487	920	0
	2016	July/August	TE	Count Unit 3, Count Unit 8	2673	637	1319	717	0
	2017	July/August	TE	Count Unit 3, Count Unit 8	2912	655	1478	779	0
	2018	July/August	TE	Count Unit 3, Count Unit 8	1381	310	735	336	0
	2019	July/August	TE	Count Unit 3, Count Unit 8	4451	973	2062	1416	0
701	2004	July	TE	Froze To Death, Plenty Creek, Sagehen	29271	7927	12817	8527	0
	2005	July	TE	Froze To Death, Plenty Creek, Sagehen	36125	8090	15963	12072	0
	2006	July	TE	Froze To Death, Plenty Creek, Sagehen	34725	7290	14963	12472	0
	2007	July	TE	Froze To Death, Plenty Creek, Sagehen	26144	6909	11799	7436	0
	2008	July	TE	Froze To Death, Plenty Creek, Sagehen	21580	5091	10972	5518	0
	2009	July	TE	Froze To Death, Plenty Creek, Sagehen	18062	3936	8445	5681	0
	2010	July	TE	Froze To Death, Plenty Creek, Sagehen	12490	3100	6772	2618	0
	2011	July, August, July	TE	Froze To Death, Plenty Creek, Sagehen	9418	2318	5209	1891	0
	2012	July, July, July	TE	Froze To Death, Plenty Creek, Sagehen	7118	1282	3845	1991	0
	2013	July, August, July	TE	Froze To Death, Plenty Creek, Sagehen	7554	1718	4436	1400	0

HD	Year	Survey Month	Survey Type	Trend Areas	Total	Bucks	Does	Fawns	Unk
	2014	July, July, July	TE	Froze To Death, Plenty Creek, Sagehen	7627	1091	3436	3100	0
	2015	August, August, July	TE	Froze To Death, Plenty Creek, Sagehen	8908	2109	3963	2836	0
	2016	August, July, July	TE	Froze To Death, Plenty Creek, Sagehen	11645	2591	5700	3354	0
	2017	July	TE	Froze To Death, Plenty Creek, Sagehen	10227	2382	4382	3463	0
	2018	July	TE	Froze To Death, Plenty Creek, Sagehen	7390	2063	3482	1845	0
	2019	July	TE	Froze To Death, Plenty Creek, Sagehen	11717	2436	5663	3618	0
705	2004	July	TE	Medicine Rocks, South Deadboy, Thompson Creek	15922	4049	6307	5565	0
	2005	July	TE	Medicine Rocks, South Deadboy, Thompson Creek	21229	6662	8017	6549	0
	2006	July	TE	Medicine Rocks, South Deadboy, Thompson Creek	23520	5936	9631	7953	0
	2007	July	TE	Medicine Rocks, South Deadboy, Thompson Creek	31602	9324	12163	10115	0
	2008	July	TE	Medicine Rocks, South Deadboy, Thompson Creek	28601	9098	11421	8082	0
	2009	July	TE	Medicine Rocks, South Deadboy, Thompson Creek	21342	6211	8243	6808	0
	2010	July	TE	Medicine Rocks, South Deadboy, Thompson Creek	17551	4259	7001	6291	0
	2011	August, July, July	TE	Medicine Rocks, South Deadboy, Thompson Creek	9743	2387	4291	3065	0
	2012	July	TE	Medicine Rocks, South Deadboy, Thompson Creek	11550	2678	4775	4097	0
	2013	July, August, July	TE	Medicine Rocks, South Deadboy, Thompson Creek	14760	4114	6146	4501	0
	2014	August, July, July	TE	Medicine Rocks, South Deadboy, Thompson Creek	14777	3549	6001	5227	0
	2015	August, August, July	TE	Medicine Rocks, South Deadboy, Thompson Creek	20358	5098	8292	6969	0
	2016	July	TE	Medicine Rocks, South Deadboy, Thompson Creek	23455	7227	9405	6824	0
	2017	July	TE	Medicine Rocks, South Deadboy, Thompson Creek	22858	6340	8679	7792	0
	2018	July	TE	Medicine Rocks, South Deadboy, Thompson Creek	25198	6001	9792	9405	0
	2019	July	TE	Medicine Rocks, South Deadboy, Thompson Creek	31521	7404	12712	11276	0
	2020	July	TE	South Deadboy	20185	5720	8331	6134	0

Objective #5: Evaluate the effect of vegetation and other landscape features on resource selection and movement of migratory and non-migratory pronghorn

5.1 Pronghorn resource selection and vegetation data collection

Pronghorn resource selection is important for the management of the species and their associated habitat. The growing season, ranging from mid-March through July, encompasses the biological period of late gestation and early lactation, which is energetically expensive and important for annual reproductive output. The primary objectives of this portion of the project are to determine what resources pronghorn select for seasonally, as well as the distribution of those resources and other important landscape features across the study areas. By evaluating vegetative resources and other landscape features that influence pronghorn resource selection, we can better understand how pronghorn move through and use the surrounding environment.

From mid-March through the end of July 2021 and 2022, we collected fine-scale vegetation data in the Musselshell, Fergus-Petroleum, and South Philips study areas. Vegetation data were collected at used locations of collared pronghorn as well as at randomly assigned available locations throughout the study areas. Used locations were identified as GPS collar locations of pronghorn and were sampled within 48-hours of pronghorn use. Available locations were sampled in proportion to available landcover type within the annual range (Figure 54). At each location a variety of vegetation attributes were measured and recorded, including species-specific percent cover, species-specific phenology, biomass of shrubs/forbs/grasses, and shrub/herbaceous plant height. At each location, we collected forage samples consisting of the earliest two available phenological stages. These samples will be sent to the lab and analyzed to determine forage quality, measured as digestible energy. In addition to vegetation samples, we collected fecal samples at known pronghorn locations and/or opportunistically to evaluate pronghorn diet. We targeted collection of 45 fecal samples each growing season, with 5 fecal samples collected from each of nine 16-day sampling periods. Fecal samples were analyzed using DNA metabarcoding. To develop a diet list of important species for each sampling period, we employed a frequency of occurrence method to refine results to only important food items.

During the 2021 and 2022 growing seasons, we sampled vegetation at 578 locations, including 287 available locations and 291 used locations (Figure 55). At all sampling sites, we identified nearly 200 different plant species. The most common vegetation recorded were sagebrush (*Artemisia*) species, common dandelion (*Taraxacum officinale*), Western wheat grass (*Pascopyrum smithii*), prairie Junegrass (*Koeleria macrantha*), and common yarrow (*Achillea millefolium*).

We collected, submitted, and received results from 45 fecal samples collected from the 2021 growing season and have submitted 42 fecal samples from the 2022 growing season. Food items listed in diet species lists (Table 7) will be used to identify forage availability of vegetation sampling sites. In 2021, the diet species list for sampling period 2 (30 Mar – 14 Apr) had the fewest food items identified (n = 9) and sampling period 7 (18 Jun – 03 Jul) had the greatest number of food items identified (n = 25). Silver sagebrush (*Artemisia cana*) and the sagebrush genus (*Artemisia* sp.) were the only food items which were identified in every sampling period. Figure 56 shows the richness of pronghorn diets during each sampling period. Forbs made up more than 50% of diet species in sampling periods 4 through 9 (01 May – 31 Jul). Shrub species made up between 20% and 41.6% of diet species throughout the spring/summer. Only 5 grass food items were identified as being used by pronghorn during 2021, however these grasses accounted for greater than 15% of food items during sampling periods 1 through 3 (14 Mar – 30 Apr).

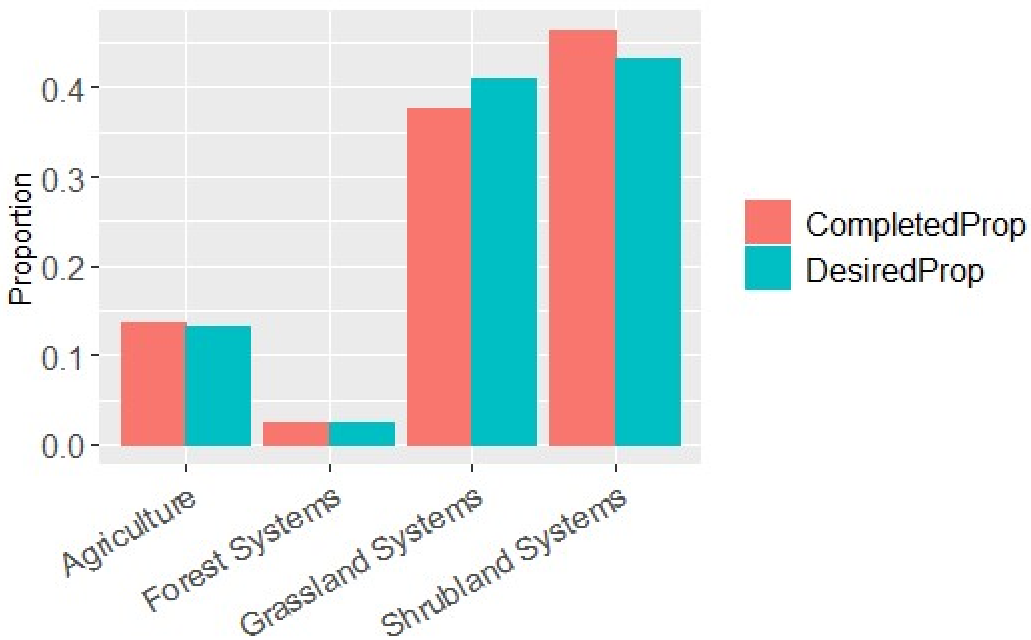


Figure 54. Proportion of available locations completed and desired (i.e., the objective proportion) in each landcover type in the Musselshell, Fergus-Petroleum, and South Philips study areas.

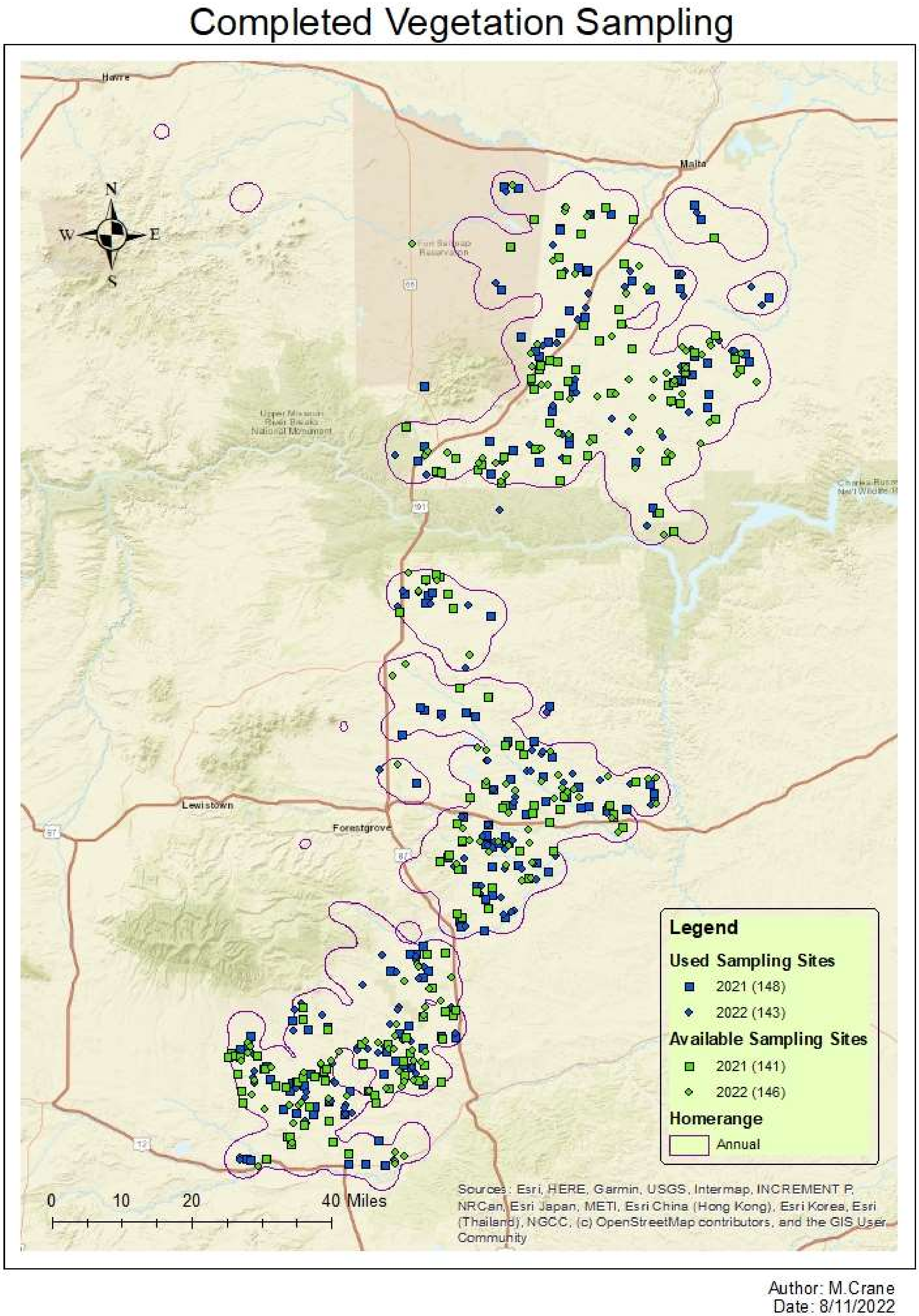
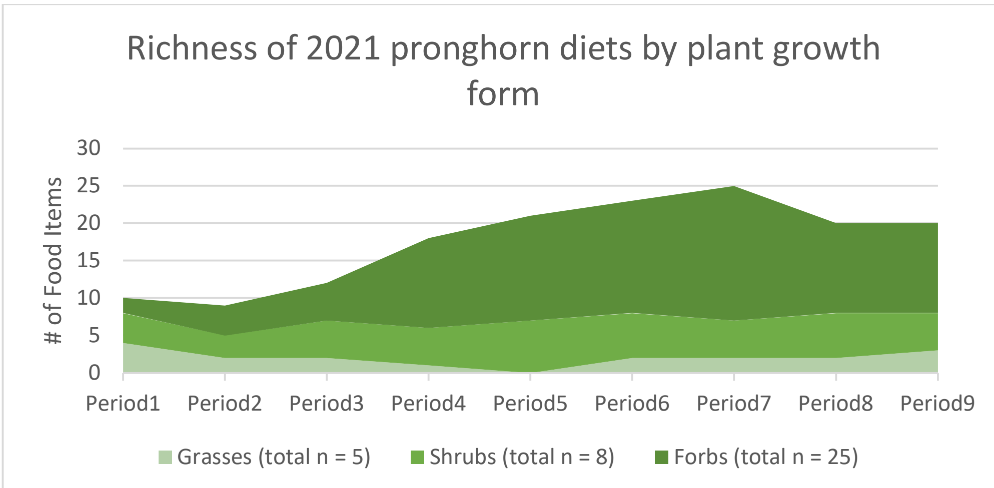


Figure 55. Map of available and used vegetation sampling locations completed in the Musselshell, Fergus-Petroleum, and South Philips study areas.

Table 7: Species in pronghorn diets based on DNA metabarcoding analysis of fecal samples for each of nine 16-day sampling periods occurring between 15 Mar and 31 Jul 2021 in the Musselshell, Fergus-Petroleum, and South Philips study areas.

Period 1 *15 Mar – 29 Mar*	**Period 2** *30 Mar – 14 Apr*	**Period 3** *15 Apr – 30 Apr*	**Period 4** *1 May – 16 May*	**Period 5** *17 May – 1 Jun*	**Period 6** *2 Jun – 17 Jun*	**Period 7** *18 Jun – 3 Jul*	**Period 8** *4 Jul – 19 Jul*	**Period 9** *20 Jul – 31 Jul*
Artemisia cana	Artemisia cana	Artemisia cana	Androsace sp.	Androsace sp.	Androsace sp.	Artemisia cana	Artemisia cana	Artemisia cana
Artemisia sp.	Artemisia sp.	Artemisia sp.	Artemisia cana	Artemisia cana	Artemisia cana	Artemisia sp.	Artemisia sp.	Artemisia sp.
Atriplex sp.	Atriplex sp.	Atriplex sp.	Artemisia sp.	Artemisia sp.	Artemisia sp.	Atriplex sp.	Atriplex sp.	Chenopodium sp.
Bromus sp.	Bromus sp.	Carex sp.	Bromus sp.	Atriplex sp.	Bromus sp.	Chenopodium sp.	Convolvulus arvensis	Comandra umbellate
Carex sp.	Eriogonum sp.	Comandra umbellate	Comandra umbellate	Comandra umbellate	Comandra umbellate	Comandra umbellate	Dalea purpurea	Convolvulus arvensis
Eriogonum sp.	Lomatium sp.	Ericameria sp.	Eriogonum pauciflorum	Ericameria sp.	Convolvulus arvensis	Convolvulus arvensis	Erigeron sp.	Dalea purpurea
Poa pratensis	Medicago sp.	Geum sp.	Eriogonum sp.	Eriogonum pauciflorum	Ericameria sp.	Dalea purpurea	Eriogonum sp.	Ericameria sp.
Poa sp.	Poa sp.	Lomatium sp.	Geum sp.	Eriogonum sp.	Eriogonum pauciflorum	Euphorbia sp.	Euphorbia sp.	Erigeron sp.
Rhus sp.	Taraxacum sp.	Poa sp.	Lomatium sp.	Glycyrrhiza lepidota	Eriogonum sp.	Glycyrrhiza lepidota	Glycyrrhiza lepidota	Eriogonum pauciflorum
Taraxacum sp.		Sarcobatus vermiculatus	Medicago sp.	Lactuca sp.	Glycyrrhiza lepidota	Grindelia sp.	Lactuca sp.	Euphorbia sp.
		Taraxacum sp.	Oenothera suffrutescens	Lepidium sp.	Lactuca sp.	Lactuca sp.	Medicago sp.	Glycyrrhiza lepidota
		Vicia sp.	Potentilla sp.	Lomatium sp.	Lomatium sp.	Lepidium sp.	Oenothera suffrutescens	Lactuca sp.
			Rosa sp.	Medicago sp.	Medicago sp.	Medicago sp.	Poa pratensis	Oenothera suffrutescens
			Sarcobatus vermiculatus	Oenothera sp.	Oenothera sp.	Oenothera suffrutescens	Poa sp.	Poa pratensis
			Sphaeralcea coccinea	Oenothera suffrutescens	Oenothera suffrutescens	Poa pratensis	Potentilla sp.	Poa sp.
			Symphoricarpos occidentalis	Rosa sp.	Rhus sp.	Potentilla sp.	Rhus sp.	Rosa sp.
			Symphyotrichum sp.	Sarcobatus vermiculatus	Rosa sp.	Rosa sp.	Rosa sp.	Sarcobatus vermiculatus
			Taraxacum sp.	Symphoricarpos occidentalis	Sarcobatus vermiculatus	Salsola sp.	Sarcobatus vermiculatus	Sphaeralcea coccinea
				Symphyotrichum sp.	Sphaeralcea coccinea	Sphaeralcea coccinea	Sphaeralcea coccinea	Symphyotrichum sp.
				Taraxacum sp.	Symphyotrichum sp.	Symphoricarpos occidentalis	Symphyotrichum sp.	Triticum aestivum
				Tragopogon dubius	Taraxacum sp.	Symphyotrichum sp.		
					Tragopogon dubius	Taraxacum sp.		
					Triticum aestivum	Tragopogon dubius		
						Triticum aestivum		
						Vicia sp.		

Figure 56: Species richness of pronghorn diets across each of nine 16-day sampling periods during the spring and early summer in the Musselshell, Fergus-Petroleum, and South Philips study areas. Early in the season, pronghorn diets consist of few species, relatively evenly split between grasses, forbs, and shrubs. However, diet species richness increases with a maximum of 25 food items identified in sampling period 7 (18 Jun – 03 Jul). Forb species contribute to greater than 50% of diet richness during sampling periods 4 – 9 (01 May – 31 Jul).



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