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Montana Pronghorn Movement & 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. A coinciding pronghorn study in the Madison Valley that began in 2019 and collected identical information was also included in this study. The primary objectives of the project were to: 1) delineate pronghorn seasonal range and movement routes in the 8 study areas; 2) create and distribute maps of pronghorn seasonal range and movement areas; 3) use pronghorn 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 pronghorn resource selection.

During winters (January – March) 2019 - 2022, we captured and instrumented with GPS collars a total of 702 adult female pronghorn, including 40 in 2019 (Madison only), 390 in 2020, 168 in 2021, and 104 in 2022. This capture effort included a total of 54 in Paradise, 82 in Madison, 85 in South Philips, 89 in Big Hole, 91 in Garfield-Rosebud, 93 in Fergus-Petroleum, 103 in Musselshell, and 105 in Powder River-Carter study areas. Across all 8 study areas, a total of 64 (9%) collars malfunctioned, 373 (53%) animals died, and 265 (38%) collars remained active at the end of the study (June 30, 2023). We collected 10,946,734 locations from 702 individuals. Monthly survival probabilities in each population generally remained stable from 2020 – 2023, ranging 0.76 (95% credible interval [CRI] 0.60 – 0.89) to 0.97 (CRI 0.92 – 0.99). Annual survival probabilities ranged from 0.62 (CRI 0.50 – 0.74) in 2023 for Powder River-Carter to 0.81 (CRI 0.71 – 0.90) in 2022 for South Philips.

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 generated study area-specific summary reports of collared pronghorn movements and mortality information and distributed 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. In addition, we mapped fences across all study areas based on aerial imagery to identify potential movement barriers and evaluate the influence of fences on pronghorn movements and behaviors. We 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 modification to more permeable fence types. We also developed a tool to identify and quantify pronghorn behavioral responses to fences that outputs interactive maps ranking fences based on these responses, which can then be used to identify problematic barriers to pronghorn movement and prioritize remediation efforts.

We developed an 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 found that adult female survival was the strongest driver of population growth; populations usually increased when adult female survival was >0.75. Four-month recruitment was also positively associated with population growth, but this effect was relatively weak compared to adult female survival. There was considerable uncertainty in the factors affecting vital rates; however, increased snow depth was related to lower adult survival and 4-month recruitment in some eastern hunting districts. Our results suggest pronghorn management should prioritize manipulation of adult female survival rates to achieve population objectives. However, IPM results were highly sensitive to assumptions regarding knowledge and confidence in aerial counts and harvest; thus, we recommend assessing the survey and inventory program to help reduce uncertainties in results and facilitate future management.

Finally, we developed summer resource selection models to support habitat conservation and management efforts for pronghorn. The primary objectives of this analysis were to 1) evaluate pronghorn selection in relation to ground-based measurements of forage and fawn security resources, and 2) evaluate how selection behavior changes correspond with changing biological needs and spatiotemporal variations in plant communities during the summer. Based on the collar location data and vegetation and diet sampling efforts completed during summers 2021 and 2022, we developed 2 summer resource selection models describing: 1) overall selection without consideration of temporal variation and 2) time-varying selection. Our non-time-varying model indicated that pronghorn selection increased with higher emergent forage cover and was optimal at 70% bare ground cover. Our time-varying model indicated that pronghorn selection for forage cover, forb digestible energy, and shrub cover varied across the summer, with some evidence for positive selection for each variable prior to and during peak spring that marginally decreased thereafter. Shrub cover, however, slightly increased during and immediately following the fawning period. Overall, this study suggests pronghorn may be balancing predation risks through their selection of fine-scale resources (i.e., by selecting areas with only slightly less bare ground than available) and varying their selection for shrub cover during the summer to avoid shrub cover once fawns become reliant on early detection to avoid predation.

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 (Yoakum 2004*a*). 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. However, there are limited data available regarding pronghorn movements and population dynamics for informing and prioritizing habitat and conservation efforts and effective management strategies throughout the state. To date, only very few pronghorn movement and demographic studies in Montana exist (e.g., Pyrah 1987, Dunn and Byers 2008, Poor et al. 2012, Jakes et al. 2018a, Jones et al. 2020), underscoring the need for more information on movements and population dynamics collected across the varying environments found throughout pronghorn range in Montana.

In addition, widespread pronghorn population declines in portions of central and eastern Montana in recent decades highlight the need for 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 throughout their range in Montana during the mid-2000s with harvest totaling 33,500 at its peak in 2007 (Montana Fish Wildlife and Parks 2020*a*). Following widespread blue-tongue virus (BTV) outbreaks in the subsequent 2 years and the record cold and snow during winter 2010-2011, harvest fell to a low of 8,200 in 2013. Pronghorn populations typically rebound quickly with favorable weather conditions (O'Gara 2004a), 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 and lead 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 constant and high due to substantial in utero maternal investment in offspring (O'Gara 2004*c*, Kohlmann 2004). However, these vital rates may be affected by habitat or weather conditions that may 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, 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).

The Montana Pronghorn Project was initiated in 2020 to address the lack of information on pronghorn movements and population dynamics and to improve our understanding of factors limiting population recovery in Montana for informing future population monitoring and management strategies. A coinciding pronghorn study in the Madison Valley that began in 2019 and collected identical information was also integrated into this project. The overall purpose of this project was to identify seasonal ranges and movement corridors and provide demographic data for pronghorn populations in 8 study areas broadly distributed across Montana (Figure 1). Our specific objectives included:

1. Delineate seasonal range and migration corridors of pronghorn in each study area.
2. Create and distribute maps of seasonal range and movements of pronghorn.
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 pronghorn resource selection.

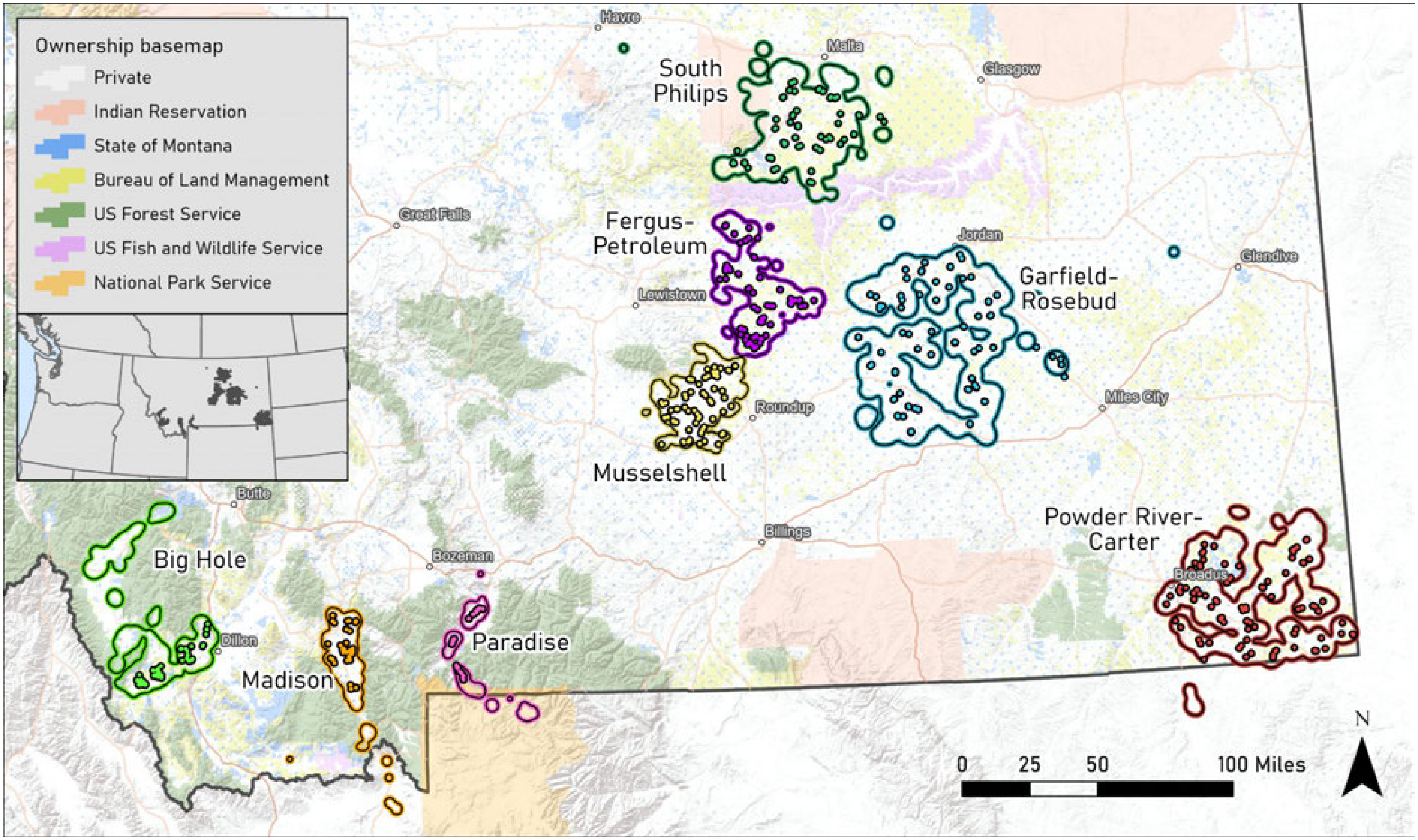


Figure 1. Capture locations (color-filled points) of all adult female pronghorn instrumented during winters 2019 – 2021 (Madison only) and 2020-2022 (all other study areas) in the 8 study areas (polygons) for the Montana Pronghorn Movement and Population Ecology Project. Study areas are represented by annual ranges calculated from 95% kernel density estimates based on collar locations.

Study locations

The 8 study areas were located in the southwestern, central, and southeastern regions of Montana (Figure 1) and included the Big Hole, Madison, Paradise, Musselshell, Fergus-Petroleum, South Philips, Garfield-Rosebud, and Powder River-Carter. These areas were selected based on local needs identified by FWP area biologists and where considerable community, conservation partner, and agency interest existed for understanding anthropogenic impediments, habitat, or other factors influencing pronghorn movement patterns or fitness. The study areas represent the annual ranges of pronghorn herds defined by 95% kernel density estimates of all GPS locations for each study area (see *Capture, instrumentation, and sampling* section).

These areas typify the open and relatively flat environments occupied by pronghorn across the majority of their range. The prairie of the central and southeast study areas was dominated by sagebrush (*Artemisia* spp.) steppe and mixed grass prairie (i.e., thickspike wheatgrass [*Elymus lanceolatus*], green needlegrass [*Nassella viridula*], blue grama [*Bouteloua gracilis*], needle and thread grass [*Hesperostipa comata*]). The southwest study areas were dominated with valley grasslands (i.e., bluebunch wheatgrass [*Pseudoroegnaria spicata*], Idaho fescue [*Festuca idahoensis*], western wheatgrass [*Pascopyrum smithii*]) interspersed with an understory of herbaceous forb species. Cultivated croplands also occur in each study area and consist mostly of common wheat and leguminous forbs (e.g., field peas, lentils, alfalfa). These agricultural lands comprised 7 – 22% of the study areas, with Paradise, Garfield-Rosebud, Madison, and Powder-River Carter having the least (7-10%) and Big Hole, South Phillips, Fergus-Petroleum, and Musselshell having the most (12-22%). Mule deer (*Odocoileus hemionus*), white-tailed deer (*O. virginianus*), and elk (*Cervus canadensis*) were sympatric with pronghorn in the study areas. Potential predators of pronghorn varied by study area and included mountain lion (*Puma concolor*), bobcat (*Lynx rufus*), gray wolf (*Canis lupis*), coyote (*C. latrans*), American black bear (*Ursus americanus*), grizzly bear (*U. arctos*), and golden eagle (*Aquila chrysaetos*).

Big Hole

The Big Hole study area (2,480 km^2) is located in Beaverhead and Deer Lodge Counties and comprises hunting districts (HD) 310 and 318 in southwestern Montana. Elevation averages 1,960 m (range: 1,535 – 2,844 m), with a 30-yr mean annual precipitation of 44 cm (range: 26 – 91 cm), July temperature of 16 °C (range: 11 - 20 °C), and January temperature of -7 °C (range: -12 to -3 °C). During the study period (2020 – 2022), mean annual precipitation was 37 cm, July temperature was 17 °C, and January temperature was -6 °C (Figure 2). Ownership was dominated by private (50%), federal (38%), and state of Montana (12%). Federal lands were managed primarily by Bureau of Land Management (BLM; 20%) and United States Forest Service (USFS; 18%).

Madison

The Madison study area (1,230 km^2) is located in Madison County and comprises HD 360 in southwestern Montana. Elevation averages 1,802 m (range: 1,469 – 2,793 m), with a 30-yr mean annual precipitation of 48 cm (range: 32 – 86 cm), July temperature of 17 °C (range: 12 - 21 °C), and January temperature of -6 °C (range: -10 to -2 °C). During the study period (2020 – 2022), mean annual precipitation was 48 cm, July temperature was 18 °C, and January temperature was -5 °C (Figure 2). Ownership was dominated by private (79%), federal (13%), and state of Montana (7%). Federal lands were managed primarily by USFS (9%) and BLM (4%).

Paradise

The Paradise study area (680 km^2) is located in Park County and comprises HD 313 in southwestern Montana. Elevation averages 1,824 m (range: 1,468 – 2,686 m), with a 30-yr mean annual precipitation of 42 cm (range: 26 – 71 cm), July temperature of 18 °C (range: 12 - 22 °C), and January temperature of -5 °C (range: -8 to -3 °C). During the study period (2020 – 2022), mean annual precipitation was 45 cm, July temperature was 19 °C, and January temperature was -4 °C (Figure 2). Ownership was dominated by federal (53%), private (43%), and state of Montana (4%). Federal lands were managed primarily by National Park Service (41%) and USFS (11%).

Musselshell

The Musselshell study area (2,140 km^2) is located in Musselshell and Golden Valley Counties and comprises HD 513 in central Montana. Elevation averages 1,203 m (range: 1,018 – 1,708 m), with a 30-yr mean annual precipitation of 38 cm (range: 36 – 53 cm), July temperature of 20 °C (range: 15 - 24 °C), and January temperature of -4 °C (range: -9 to 2 °C). During the study period (2020 – 2022), mean annual precipitation was 35 cm, July temperature was 21 °C, and January temperature was -3 °C (Figure 2). Ownership was dominated by private (85%), federal (9%), and state of Montana (6%). Federal lands were managed primarily by BLM (7%).

Fergus-Petroleum

The Fergus-Petroleum study area (2,550 km^2) is located in Fergus and Petroleum Counties and comprises HD 481 and 420 in central Montana. Elevation averages 949 m (range: 753 – 1,296 m), with a 30-yr mean annual precipitation of 36 cm (range: 34 – 47 cm), July temperature of 22 °C (range: 16 - 25 °C), and January temperature of -5 °C (range: -11 to 3 °C). During the study period (2020 – 2022), mean annual precipitation was 30 cm, July temperature was 23 °C, and January temperature was -3 °C (Figure 2). Ownership was dominated by private (69%), federal (24%), and state of Montana (6%). Federal lands were managed primarily by BLM (24%).

South Philips

The South Philips study area (4,500 km^2) is located in Philips County and comprises HD 620 in north-central Montana. Elevation averages 818 m (range: 684 – 1,237 m), with a 30-yr mean annual precipitation of 36 cm (range: 32 – 45 cm), July temperature of 21 °C (range: 16 - 25 °C), and January temperature of -7 °C (range: -14 to 1 °C). During the study period (2020 – 2022), mean annual precipitation was 29 cm, July temperature was 23 °C, and January temperature was -5 °C (Figure 2). Ownership was dominated by private (56%), federal (37%), and state of Montana (7%). Federal lands were managed primarily by BLM (35%).

Garfield-Rosebud

The Garfield-Rosebud study area (7,570 km^2) is located primarily in Garfield and Rosebud Counties and comprises HD 701 in central Montana. Elevation averages 906 m (range: 765 – 1,131 m), with a 30-yr mean annual precipitation of 36 cm (range: 32 – 43 cm), July temperature of 22 °C (range: 17 - 26 °C), and January temperature of -6 °C (range: -12 to 2 °C). During the study period (2020 – 2022), mean annual precipitation was 32 cm, July temperature was 23 °C, and January temperature was -3 °C (Figure 2). Ownership was dominated by private (87%), state of Montana (7%), and federal (6%). Federal lands were managed primarily by BLM (6%).

Powder River-Carter

The Powder River-Carter study area (6,060 km^2) is located in Powder River and Carter Counties and comprises HD 705 in southeastern Montana. Elevation averages 1,042 m (range: 853 – 1,358 m), with a 30-yr mean annual precipitation of 40 cm (range: 37 – 47 cm), July temperature of 22 °C (range: 17 - 25 °C), and January temperature of -6 °C (range: -11 to 1 °C). During the study period (2020 – 2022), mean annual precipitation was 34 cm, July temperature was 23 °C, and January temperature was -4 °C (Figure 2). Ownership was dominated by private (63%), federal (27%), and state of Montana (10%). Federal lands were managed primarily by BLM (26%).

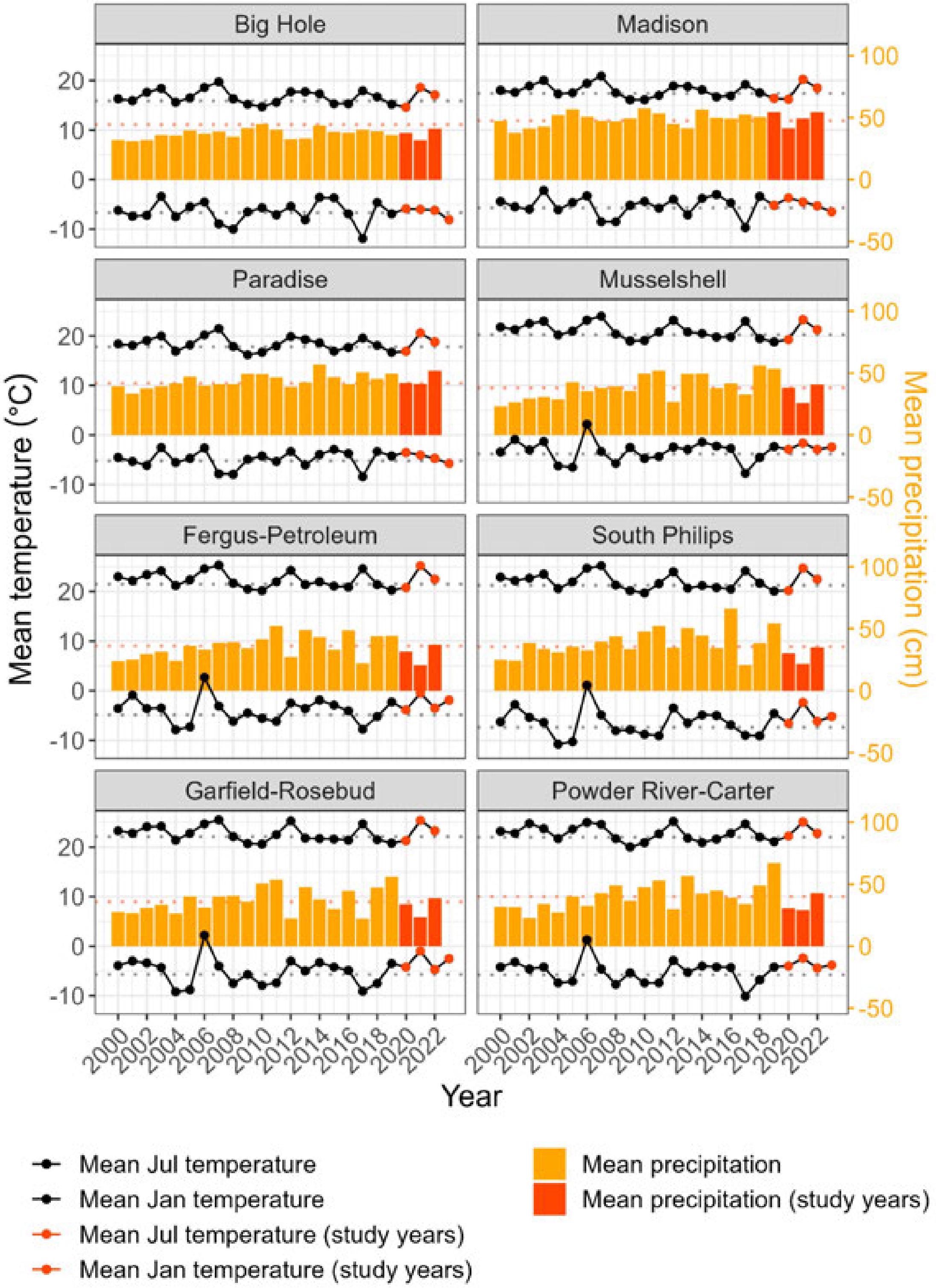


Figure 2. Climographs showing annual mean January and July temperatures (left axis) and precipitation (right axis) for each study area from 2000 – 2023 in the Montana Pronghorn Movement and Population Ecology Project. The dark orange points and bars represent values during the years of the study (2020 – 2023 for all except Madison, which additionally included 2019). Dotted lines represent respective 30-year temperature and precipitation averages. The missing precipitation and July temperature data for 2023 is due to the reporting period end date of June 30, 2023.

Capture, instrumentation, & sampling

Across all study areas during winters (January – March) 2019 to 2022, we captured and instrumented with GPS collars a total of 702 adult female pronghorn, including 40 in 2019 (Madison only), 390 in 2020, 168 in 2021, and 104 in 2022 (excluding the Madison; Table 1). From 2020 - 2022, we sought to maintain approximately 60 animals with active collars in each study area; however, accessibility and distribution of animals limited our sampling success in the Big Hole and Paradise. 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 uploaded locations via Iridium satellites to a web platform for viewing and downloading near-real-time data. We monitored collared animals through June 30, 2023.

Table 1. Collaring accomplishments in each study area during winters of 2019 – 2021 (Madison only) and 2020 – 2022 (all remaining study areas).

	2019	2020	2021	2022	Total
Big Hole	-	46	31	12	89
Madison	40	20	22	-	82
Paradise	-	24	22	8	54
Musselshell	-	60	19	24	103
Fergus-Petroleum	-	60	18	15	93
South Philips	-	60	16	9	85
Garfield-Rosebud	-	60	18	13	91
Powder River-Carter	-	60	22	23	105
Total	40	390	168	104	702

During the 2019 (Madison only) and 2020 captures, we collected blood serum from each animal for disease screening. In 2021, we collected additional blood samples only in the Big Hole and Paradise study areas due to the prior years limited sample sizes. Blood serum samples were assayed for evidence of exposure to pathogens including *Anaplasma* bacteria, bovine herpesvirus, bovine respiratory syncytial virus, bluetongue virus, bovine viral diarrhea type 1, bovine viral diarrhea type 2, epizootic hemorrhagic disease, *Leptospira canicola*, *L. grippo*, *L. hardjo*, *L. ictero*, *L. pomona*, and parainfluenza-3. These pathogens were selected for screening because of either their known potential impact to individual or herd health (e.g., bluetongue virus and epizootic hemorrhagic disease) and/or because of their known association with livestock or wildlife health (e.g., *Leptospira* serovars, *Anaplasma*, bovine viral syncytial virus, and parainfluenza-3. All assays were conducted by the Montana Veterinary Diagnostic Laboratory (Bozeman, Montana), except for epizootic hemorrhagic disease which was conducted by the Washington Animal Disease Diagnostic Lab (Pullman, Washington). Evidence for exposure varied by pathogen and study area (Table 2). We found no serological evidence of exposure in any study area for bovine herpesvirus or *L. hardjo*. We found evidence of exposure in all study areas for *Anaplasma* (ranging from 16 – 92% seroprevalence), *L. ictero* (ranging from 1 – 20% seroprevalence), and parainfluenza-3 (ranging from 75 – 100% seroprevalence). Below, we discuss each of the pathogens identified through serology in our study areas.

Anaplasmosis, or gall sickness, is a disease of blood cells primarily affecting domestic cattle that is caused by *Anaplasma* bacteria and transmitted by ectoparasites. Pronghorn are susceptible to infection of *Anaplasma*; however, serious clinical signs have not been recorded in pronghorn and little evidence exists that pronghorn act as important carriers (Kuttler 1984, O'Gara 2004*b*). We found serological evidence for exposure to *Anaplasma* in all study areas with seroprevalence averaging 52% (range: 16 – 85%) with Big Hole having the lowest seroprevalence and Paradise having the highest seroprevalence. Although we found evidence of exposure across all study areas, these results are not expected to impact individual or herd health.

Bovine respiratory syncytial virus is an infection associated with respiratory disease primarily affecting domestic cattle that can cause the formation of syncytial cells – the fusion of infected cells with neighboring cells. Pronghorn are susceptible to infection by the virus, which is most likely transmitted from cattle; however, serious clinical signs have not been recorded in pronghorn (O'Gara 2004*b*). We found serological evidence of low levels of exposure to bovine respiratory syncytial virus in only the Big Hole (6%), Musselshell (5%), and Paradise (4%) study areas. Although evidence of exposure occurred in each of these study areas, these results are not expected to impact individual or herd health (O'Gara 2004*b*).

Bluetongue virus is transmitted by biting midges in the *Culicoides* genus and other arthropods and can cause acute and frequently fatal hemorrhagic disease in domestic and wild ungulates. Pronghorn are susceptible to disease caused by the bluetongue virus which can result in large, all-sex and -age die-offs that occur primarily during late summer and early autumn (Thorne et al. 1988, O'Gara 2004*b*). There is evidence that pronghorn can, however, be exposed to this virus without suffering high rates of mortality or showing clinical signs (O'Gara 2004*b*). Exposure to bluetongue virus was only detected in Garfield-Rosebud (5%). These results were not atypical of exposure rates observed in pronghorn and do not necessarily indicate pathogenicity (O'Gara 2004*b*, Dubay et al. 2006).

Epizootic hemorrhagic disease virus is transmitted by biting midges in the *Culicoides* genus and other arthropods and can cause acute and frequently fatal hemorrhagic disease in domestic and wild ungulates. Pronghorn are susceptible to epizootic hemorrhagic disease which can result in large, all-sex and -age die-offs that occur primarily during late summer and early autumn. There is evidence that pronghorn can, however, be exposed to this virus without suffering high rates of mortality or showing clinical signs (O'Gara 2004*b*, Gray 2013). Epizootic hemorrhagic disease virus exposure was detected in all study areas except Big Hole, Madison, and Paradise, with seroprevalence averaging 22% (ranging 12 – 39%) in study areas where exposure was detected. These results were not atypical of exposure rates observed in pronghorn and do not necessarily indicate pathogenicity (Barrett and Chalmers 1975, O'Gara 2004*b*, Gray 2013).

Bovine viral diarrhea (types 1 & 2) is a disease caused by a virus that causes diarrhea and can induce immunosuppression, which allows for development of secondary bacterial pneumonia in domestic and wild ungulates. The different types (1 & 2) reflect differences in the antigens found on the viral surface protein and do not relate to the virulence of the virus. Pronghorn are susceptible to infection of bovine viral diarrhea, however, there is little evidence of serious clinical effects or that pronghorn act as important carriers. We found a low seroprevalence of both types of bovine viral diarrhea in the majority of study areas (0 – 7%) and seroprevalence of 41% for bovine viral diarrhea type 2 in Fergus-Petroleum. These seroprevalences were similar to those found in Alberta and Saskatchewan where no clinical signs were observed (Barrett and Chalmers 1975, Kingscote and Bohac 1986).

Leptospira spp. are members of an infective serological group of bacteria that can infect nearly all mammals. Infection varies in severity from asymptomatic to fatal depending on the host and the serovar of *Leptospira*. Naturally occurring Leptospira infections in wildlife are usually asymptomatic, but may result in renal failure, lysis of red blood cells, fever, inappetence, hemorrhages on mucous membranes, jaundice, dehydration, infertility, abortion, stillbirths, or weakened neonates. Pronghorn are susceptible to *Leptospira* spp. infection which may cause some mortality; however, clinical disease in wildlife is rare and not likely a major limiting factor in pronghorn populations (O'Gara 2004*b*). We found low seroprevalence (1%) to *L. grippo* and *L. pomona* in only the Big Hole, low seroprevalence (2%) to *L. canicola* in only the Paradise, and low to moderate seroprevalence to *L. ictero* that averaged 12% (ranging 7 – 20%) in all study areas. Although few previous studies have reported exposure to these Leptospira serovars in pronghorn and cross-reactivity of serovars makes interpretation of seroprevalence challenging, we do not suspect our results indicate pathogenicity and are within the range of normal exposure rates to other serovars of *Leptospira* in pronghorn (O'Gara 2004*b*).

Parainfluenza-3 is a virus capable of causing respiratory disease in domestic ungulates. The disease is usually associated with mild to subclinical infections, but may serve an important role as an initiator under severe stress that can lead to development of secondary bacterial pneumonia. Parainfluenza-3 exposure is highly variable among pronghorn from different areas and across years; however, there is no evidence of serious disease and the virulence is unknown in pronghorn (Barrett and Chalmers 1975, O'Gara 2004*b*, Dubay et al. 2006). We found an average seroprevalence of 91% (ranging from 75 – 100%) to parainfluenza-3 across all populations with Big Hole having the lowest seroprevalence and Madison and Powder River-Carter having the highest seroprevalence. Although evidence of exposure occurred in each study area, these results are not expected to impact individual or herd health (Barrett and Chalmers 1975, Stauber et al. 1980, O'Gara 2004*b*).

Table 2. Seroprevalence for anaplasmosis (ANPLSM), bovine herpesvirus (BHV), bovine respiratory syncytial virus (BRSV), bluetongue virus (BTV), bovine viral diarrhea type 1 (BVD1), bovine viral diarrhea type 2 (BVD2), epizootic hemorrhagic disease (EHD), *Leptospira canicola* (L. CAN), *L. grippo* (L. GRI), *L. hardjo* (L. HAR), *L. ictero* (L. ICT), *L. pomona* (L. POM), and parainfluenza-3 (PI3) based on serological screening of adult female pronghorn sampled in the Madison during winter 2019, all study areas during winter 2020, and in the Big Hole and Paradise during winter 2021.

Herd	Statistic	ANPLSM	BHV	BRSV	BTV	BVD1	BVD2	EHD	L. CAN	L. GRI	L. HAR	L. ICT	L. POM	PI3
Big Hole	# Sampled	76	76	76	76	76	76	75	76	76	76	76	76	76
	# Exposed	12	0	6	0	0	0	0	0	1	0	7	1	57
	% Exposed	16	0	8	0	0	0	0	0	1	0	9	1	75
Madison	# Sampled	21	21	21	21	21	21	21	21	21	21	21	21	21
	# Exposed	13	0	0	0	0	1	0	0	0	0	2	0	21
	% Exposed	62	0	0	0	0	< 1	0	0	0	0	< 1	0	100
Paradise	# Sampled	47	47	47	47	47	47	34	47	47	47	47	47	47
	# Exposed	40	0	4	0	0	1	0	1	0	0	8	0	42
	% Exposed	75	0	9	0	0	2	0	2	0	0	17	0	90
Musselshell	# Sampled	59	58	58	59	57	57	22	59	59	59	59	59	57
	# Exposed	33	0	3	0	0	2	3	0	0	0	4	0	48
	% Exposed	56	0	5	0	0	4	14	0	0	0	7	0	84
Fergus-Petroleum	# Sampled	61	61	61	61	61	61	58	61	61	61	61	61	61
	# Exposed	33	0	0	0	1	25	14	0	0	0	8	0	59
	% Exposed	54	0	0	0	2	41	24	0	0	0	13	0	97
South Philips	# Sampled	60	60	60	60	60	60	58	60	60	60	60	60	60
	# Exposed	32	0	0	0	1	4	7	0	0	0	7	0	58
	% Exposed	53	0	0	0	2	7	12	0	0	0	12	0	97
Garfield-Rosebud	# Sampled	61	61	61	61	61	61	49	61	61	61	61	61	61
	# Exposed	21	0	0	3	0	2	9	0	0	0	7	0	52
	% Exposed	34	0	0	5	0	3	18	0	0	0	12	0	85
Powder River-Carter	# Sampled	61	57	57	61	61	61	33	61	61	61	61	61	57
	# Exposed	36	0	0	0	2	1	13	0	0	0	12	0	56
	% Exposed	59	0	0	0	3	2	39	0	0	0	20	0	98

Survival monitoring & analysis

Of the 702 collared animals, 373 (53%) died, ranging 24 – 61 (44 – 67%) animals in each study area, and 64 (9%) collars malfunctioned, ranging 3 – 15 (3 – 22%) collars in each study area (Figure 3). Mortality investigations were completed as soon as possible after receiving the mortality alerts. We classified each mortality causation as "certain" or "probable" depending on the level of evidence available at the mortality site; however, given the challenges in determining certainty in mortality causes for pronghorn (e.g., limited ability to investigate mortalities before evidence is gone), we consider all recorded mortality causes as "probable" and report them here as such. When possible, we collected incisors from each mortality to estimate age using cementum age analysis performed by Matson's Laboratory, Montana. 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 4; Table 3). The remaining mortalities were classified as unknown (n = 136), predation (n = 87), natural (n = 35), legal harvest (n = 36), disease (n = 20), human-related (n = 11), injury (n = 8), starvation (n = 3) and illegal take (n = 4). We classified mortalities as natural when evidence suggested the cause was due to other mechanisms, such as birth complications, or when a carcass was found intact with little evidence to classify otherwise. Many natural mortalities included animals that were suspect of having disease but pathology results from sampled organs were negative or inconclusive. Of the predation mortalities, we classified 56 as coyote, 7 as mountain lion, 5 as bobcat, 3 as canid, and 15 as unknown. We classified mortalities as disease when evidence from field necropsy (e.g., abnormal spots, lesions, or hemorrhaging on internal organs that did not appear to be injury-related) and/or disease testing results suggested a disease-causing organism was present in organ tissues. When possible, we sampled mortalities by collecting fresh tissue from various internal organs and analyzed for hemorrhagic disease testing at the Southeastern Cooperative Wildlife Disease Study, Georgia, and/or for other disease testing at the Montana Veterinary Diagnostic Laboratory, Bozeman. Of the disease mortalities, we sampled a total of 19 (95%), with 13 tested for hemorrhagic disease and 10 tested for other diseases. Nine (45% of total disease mortalities) tested positive for hemorrhagic disease, with 6 testing positive for epizootic hemorrhagic disease (EHD) virus and 3 testing positive for blue tongue virus (BTV). Fergus-Petroleum comprised 1 EHD positive, Garfield-Rosebud comprised 2 EHD positive, Powder River-Carter comprised 2 EHD and 3 BTV positive, and South Philips comprised 1 EHD positive result. Of the remaining disease mortalities that were sampled and submitted for other disease testing (including 2 samples that tested negative and 7 samples that were not submitted for hemorrhagic disease), 5 (25% of total disease mortalities) had evidence of pneumonia, 3 (15% of total) septicemia, and 1 (5% of total) lung cancer. The remaining 2 (10% of total) disease mortalities that tested negative for hemorrhagic disease and were not submitted for other disease testing were suspected as EHD or BTV during field necropsy, but no disease or disease-causing agent could otherwise be verified. Of the human-related mortalities, we classified 6 as vehicle collisions, 3 as harvest wounding loss, 1 as train collision, and 1 as snared. A total of 265 (38% of total collared) collared animals were on air at the end of the study (June 30, 2023).

We collected a total of 129 incisors for aging animals at time of mortality. The average age was 5.7 years (range: 1 – 12 years) and varied by study area (Table 4), with the oldest average ages occurring in the Big Hole (7.9 years), Paradise (6.7 years), and Madison (6.2 years), and the youngest average ages occurring in the Fergus-Petroleum (4.5 years), Garfield-Rosebud (4.8 years), and Powder River-Carter (4.9 years). The oldest individuals occurred in the Big Hole (12 years) and Paradise (12 years) study areas. Average age varied by mortality cause (Table 5), with human-related wounding loss (8 years), vehicle collision (7.5 years), and predation (6.2) comprising the oldest average age individuals and illegal take (2 years), injury (4.2 years), capture (4.9 years), and disease (4.9 years) comprising the youngest average age individuals.

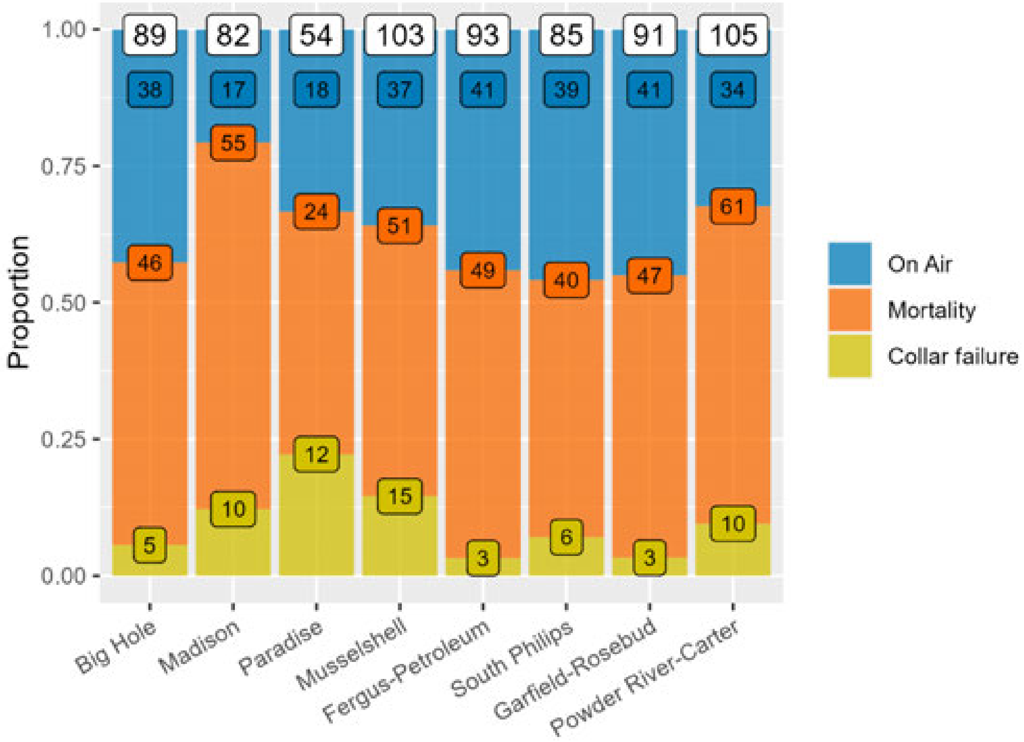


Figure 3. Number and proportion of total collared adult female pronghorn remaining on air, dead, or with a malfunctioned collar in each study area across 2019 – 2023 in the Montana Pronghorn Movement and Population Ecology Project as of June 30, 2023. The total number of collared animals in each study area is labeled at the top of each bar.

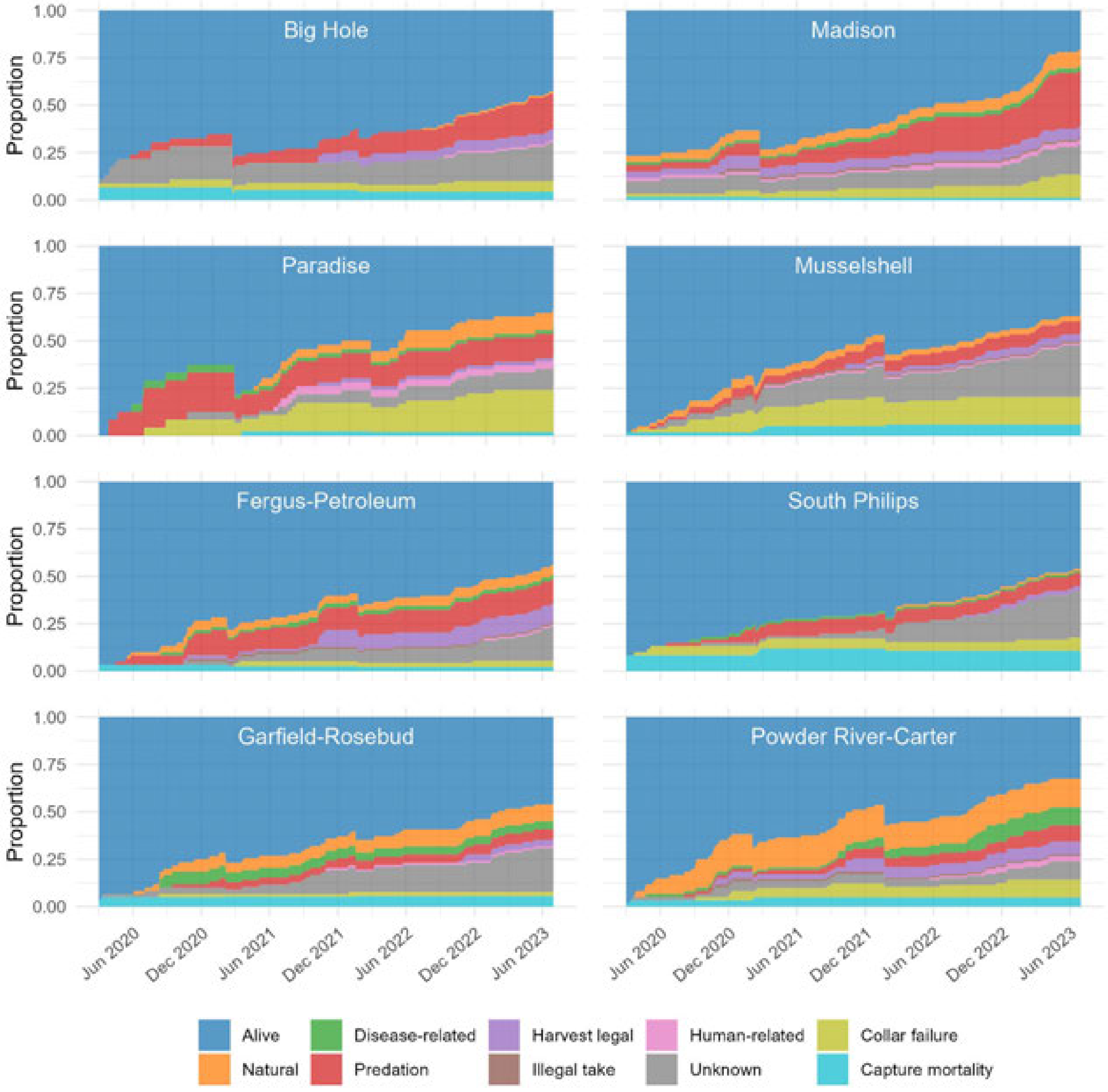


Figure 4. Proportion of the total collared adult female pronghorn alive, dead, or with a malfunctioned collar in each study area in the Montana Pronghorn Movement and Population Ecology Project spanning from January 2020 to June 2023. Cause of death was determined by field investigations. Note that this figure does not include data collected in 2019 in the Madison study area.

Table 3. Number (and proportion) of each probable mortality cause in each study area and year in the Montana Pronghorn Movement and Population Ecology Project, 2020 – 2023* (2019 – 2023* for Madison). Cause of death was determined by field investigations. *Note that 2023 only includes January - June.

Herd	Mortality Cause	2019	2020	2021	2022	2023*	Total
Big Hole	Capture	--	3 (0.21)	1 (0.11)	--	--	4
	Natural	--	--	--	1 (0.07)	--	1
	Predation - coyote	--	2 (0.14)	2 (0.22)	6 (0.43)	4	14
	Predation - unknown	--	1 (0.07)	1 (0.11)	1 (0.07)	--	3
	Harvest legal	--	--	4 (0.44)	1 (0.07)	--	5
	Human-related - vehicle collision	--	--	--	1 (0.07)	--	1
	Unknown	--	8 (0.57)	1 (0.11)	4 (0.29)	5 (0.56)	18
	Total	--	14	9	14	9	39
Madison	Capture	--	1 (0.10)	--	--	--	1
	Natural	--	--	1 (0.12)	1 (0.07)	--	2
	Injury	1 (0.10)	1 (0.10)	--	--	--	1
	Starvation	1 (0.10)	--	--	--	2 (0.15)	1
	Disease	1 (0.10)	--	1 (0.12)	--	--	2
	Predation - coyote	2 (0.20)	2 (0.20)	1 (0.12)	4 (0.29)	5 (0.38)	9
	Predation - canid	--	--	1 (0.12)	--	--	1
	Predation - lion	--	--	--	1 (0.07)	--	1
	Predation - unknown	--	--	2 (0.25)	3 (0.21)	2 (0.15)	5
	Harvest legal	2 (0.20)	2 (0.20)	--	1 (0.07)	--	5
	Illegal take	--	1 (0.10)	--	--	--	1
	Human-related - vehicle collision	--	--	--	1 (0.07)	--	1
	Human-related - train collision	--	1 (0.10)	--	--	--	1
	Unknown	3 (0.30)	2 (0.20)	2 (0.25)	3 (0.21)	3 (0.23)	11
	Total	10	10	8	14	13	43
Paradise	Capture	--	--	1 (0.11)	--	--	1
	Natural	--	--	2 (0.22)	3 (0.50)	--	5
	Disease	--	1 (0.14)	--	--	--	1
	Predation - canid	--	2 (0.29)	--	--	--	2
	Predation - lion	--	2 (0.29)	1 (0.11)	1 (0.17)	--	4
	Predation - unknown	--	1 (0.14)	--	--	--	1
	Harvest legal	--	--	1 (0.11)	--	--	1
	Human-related - vehicle collision	--	--	2 (0.22)	--	--	2
	Unknown	--	1 (0.14)	2 (0.22)	2 (0.33)	2 (1.00)	5
	Total	--	7	9	6	2	22
Musselshell	Capture	--	1 (0.08)	3 (0.17)	2 (0.15)	--	6
	Natural	--	1 (0.08)	--	--	--	1
	Injury	--	2 (0.17)	--	--	--	2
	Predation - coyote	--	3 (0.25)	1 (0.06)	1 (0.08)	--	5
	Predation - lion	--	--	2 (0.11)	--	--	2
	Harvest legal	--	--	2 (0.11)	2 (0.15)	--	4
	Illegal take	--	1 (0.08)	--	--	--	1
	Human-related - vehicle collision	--	--	1 (0.06)	--	--	1
	Unknown	--	4 (0.33)	9 (0.50)	8 (0.62)	8 (1.00)	21
	Total	--	12	18	13	8	43
Fergus-Petroleum	Capture	--	2 (0.12)	--	--	--	2
	Natural	--	2 (0.12)	--	1 (0.08)	--	3
	Injury	--	1 (0.06)	--	1 (0.08)	--	2
	Disease	--	1 (0.06)	1 (0.08)	--	--	2
	Predation - coyote	--	6 (0.35)	1 (0.08)	3 (0.23)	--	10
	Predation - unknown	--	2 (0.12)	--	--	--	2
	Harvest legal	--	1 (0.06)	6 (0.50)	2 (0.15)	--	9

Herd	Mortality Cause	2019	2020	2021	2022	2023*	Total
	Illegal take	--	1 (0.06)	--	--	--	1
	Human-related - snare	--	--	--	1 (0.08)	--	1
	Unknown	--	1 (0.06)	4 (0.33)	5 (0.38)	7 (1.00)	10
	Total	--	17	12	13	7	42
South Philips	Capture	--	5 (0.56)	4 (0.40)	--	--	9
	Natural	--	--	--	1 (0.07)	--	1
	Disease	--	1 (0.11)	--	--	--	1
	Predation - coyote	--	2 (0.22)	4 (0.40)	--	--	6
	Harvest legal	--	--	--	2 (0.13)	--	2
	Unknown	--	1 (0.11)	2 (0.20)	12	6 (1.00)	16
	Total	--	9	10	15	6	35
Garfield-Rosebud	Capture	--	3 (0.20)	1 (0.08)	1 (0.08)	--	5
	Natural	--	3 (0.20)	1 (0.08)	3 (0.25)	--	7
	Injury	--	1 (0.07)	--	--	--	1
	Disease	--	4 (0.27)	--	--	--	4
	Predation - coyote	--	2 (0.13)	2 (0.15)	1 (0.08)	--	5
	Harvest legal	--	--	--	3 (0.25)	--	3
	Human-related - wounding loss	--	--	1 (0.08)	--	--	1
	Unknown	--	2 (0.13)	8 (0.62)	4 (0.33)	7 (1.00)	17
	Total	--	15	13	12	7	43
Powder River-Carter	Capture	--	2 (0.10)	2 (0.11)	1 (0.06)	--	5
	Natural	--	10 (0.50)	4 (0.22)	1 (0.06)	--	15
	Injury	--	--	--	1 (0.06)	--	1
	Disease	--	1 (0.05)	3 (0.17)	6 (0.35)	--	10
	Predation - coyote	--	--	2 (0.11)	--	--	2
	Predation - bobcat	--	1 (0.05)	1 (0.06)	1 (0.06)	2 (0.33)	5
	Predation - unknown	--	--	1 (0.06)	1 (0.06)	--	2
	Harvest legal	--	2 (0.10)	4 (0.22)	1 (0.06)	--	7
	Illegal take	--	1 (0.05)	--	--	--	1
	Human-related - wounding loss	--	--	--	2 (0.12)	--	2
	Human-related - vehicle collision	--	--	--	1 (0.06)	--	1
	Unknown	--	3 (0.15)	1 (0.06)	2 (0.12)	4 (0.67)	6
	Total	--	20	18	17	6	57

Table 4. Summary of age at mortality for each study area in the Montana Pronghorn Movement and Population Ecology Project. Ages were estimated based on cementum analyses of incisors collected at time of death during 2020 – 2023 (2019 – 2023 for Madison).

	Total	Mean Age	SD	Min. Age	Max. Age
Big Hole	15	7.9	3.5	2	12
Madison	11	6.2	2.3	4	10
Paradise	17	6.7	3.3	1	12
Musselshell	9	6.2	2.4	3	10
Fergus-Petroleum	11	4.5	2.4	2	9
South Philips	4	5.2	2.1	3	7
Garfield-Rosebud	25	4.8	2.6	1	10
Powder River-Carter	37	4.9	2.1	2	10
Overall	129	5.7	2.8	1	12

Table 5. Summary of age at mortality for probable mortality causes for the Montana Pronghorn Movement and Population Ecology Project. Ages were estimated based on cementum analyses of incisors collected at time of death during 2020 – 2023 (2019 – 2023 for Madison).

Mortality cause	Total	Mean Age	SD	Min. Age	Max. Age
Capture	10	4.9	2.2	2	8
Disease	17	4.9	2.1	1	9
Injury	6	4.2	1.9	2	7
Natural	28	5.4	2.4	2	10
Predation	32	6.2	3.1	1	12
Harvest legal	3	6	3.6	2	9
Illegal take	1	2	--	2	2
Human-related – wounding loss	3	8	2	6	10
Human-related – vehicle collision	4	7.5	2.5	5	11
Unknown	25	5.9	3.4	1	12

Based on known fate information from the collared pronghorn, we estimated monthly survival within and across populations (Figure 5) and annual survival by population (Figure 6, Table 6) for 3 biological years spanning 01 Jun – 31 May (i.e., 2020 – 2021, 2021 – 2022, and 2022 – 2023). 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 (i.e., alive or dead) and transition between states on survival rates. We built the model using an encounter history of length = 36 (36 months across 3 years) which includes 3 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 results from the model estimate survival as 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 (Figure 5) and then estimate annual survival by taking the product of all 12 months' survival probabilities within each year and population (Figure 6, Table 6).

Monthly survival probabilities across study areas varied between 0.76 (95% credible interval [CRI] 0.60 – 0.89) and 0.97 (CRI 0.92 – 0.99), with the lowest occurring in Apr 2023 and the highest commonly occurring in several months and years (Figure 5). The lowest monthly survival estimates occurred in Apr 2023 in Madison (0.76, CRI 0.60 – 0.89), July 2020 in Paradise (0.87, CRI 0.73 – 0.96), and June 2022 in Paradise (0.87, CRI 0.74 – 0.96). There were only 10 months (4%) across the entire study duration and study areas where monthly survival estimates were estimated to be less than 0.90, which occurred in Madison (Mar and Apr 2023), Paradise (Jul 2020, Nov 2020, and Jun 2022), Fergus-Petroleum (Nov 2020, Nov 2021, and Oct 2022), and Powder River-Carter (Nov 2021 and Oct 2022) study areas. The majority (55%) of months across the entire study duration and study areas were estimated to have monthly survival rates of 0.95 or greater.

Annual survival estimates within populations indicated slight increases in point estimates from 2021 to 2022 in most populations (excluding Big Hole, Madison, and Paradise) and slight decreases in point estimates from 2022 to 2023 in most populations (excluding Paradise and Fergus-Petroleum). Annual survival estimates ranged from a low of 0.57 (CRI 0.43 - 0.71) in 2023 for Madison to a high of 0.81 (CRI 0.71 - 0.90) in 2022 for South Philips (Figure 6; Table 6). However, credible intervals overlapped substantially across most years within populations and across all populations, suggesting that there was no difference in annual survival between some years for each population and across populations. The survival estimates reported here include 33 harvested individuals from all 8 of the populations. Most of the pronghorn (17 of 33) were harvested in 2021, with the majority from the Fergus-Petroleum (n = 7) and Powder River-Carter herds (n = 6).

To examine relationships between environmental conditions and pronghorn survival at the study area level, we collected 4 covariates to represent 3 hypotheses: drought, winter severity (percent snow cover and number of days below -10C), and nutrient availability. We aggregated data to monthly values for each population using Google Earth Engine (Gorelick et al. 2017). For drought, we used the Palmer Drought Severity Index (PDSI) from the 4-km daily Gridded Surface Meteorological (GRIDMET) dataset (Palmer 1965, Abatzoglou 2013). We calculated a median monthly value from the daily GRIDMET dataset and then calculated the median value of these to aggregate the 4 km cells to each study area scale. PDSI values less than 0 indicated drier conditions and while values greater than 0 indicated wetter conditions (Palmer 1965). To quantify winter severity, we calculated 2 variables: percent snow cover and the number of cold days below the lower critical thermal temperature of pronghorn (-10°C; Pyle 1972, Yoakum 2004*c*, Brinkman et al. 2005). To quantify percent snow cover, we used the daily 500 m resolution MODIS dataset (Hall and Riggs 2011). We calculated a mean value per month for each study area to aggregate to the appropriate spatiotemporal scale. We calculated harsh cold at the study area level as the number of days per month with a nighttime low below -10°C, based on the lower critical temperature for pronghorn (Byers 1997). We aggregated the 1-km MODIS dataset to the study area by taking the maximum value of the pixels in that study area. Finally, we represented nutrient availability throughout the year using the normalized difference vegetation index (NDVI; Zhang et al. 2003). We aggregated the 16-day dataset to month by taking the median value and then aggregated to study area by taking the median value of 1-km pixels.

Upon evaluating environmental covariate influences on pronghorn survival across all sex and age classes, we did not find any relationship between survival and cold temperatures, percent snow cover, drought severity, or NDVI (Figure 7).

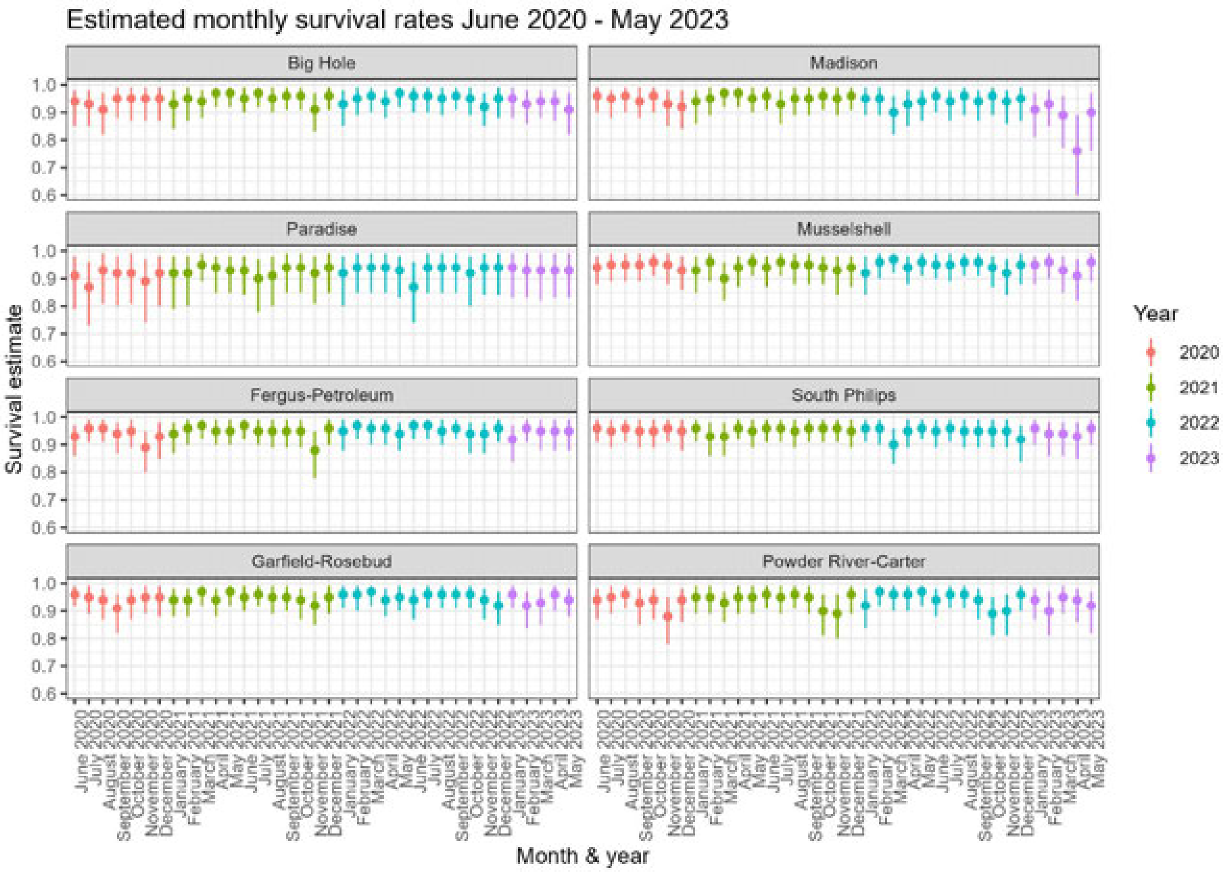


Figure 5. Mean monthly survival probabilities (and 95% credible intervals) for each study area and biological year (2021 = 01 Jun 2020 – 31 May 2021; 2022 = 01 Jun 2021 – 31 May 2022; 2023 = 01 Jun 2022 – 31 May 2023) estimated from known fate information of collared adult female pronghorn in the Montana 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.

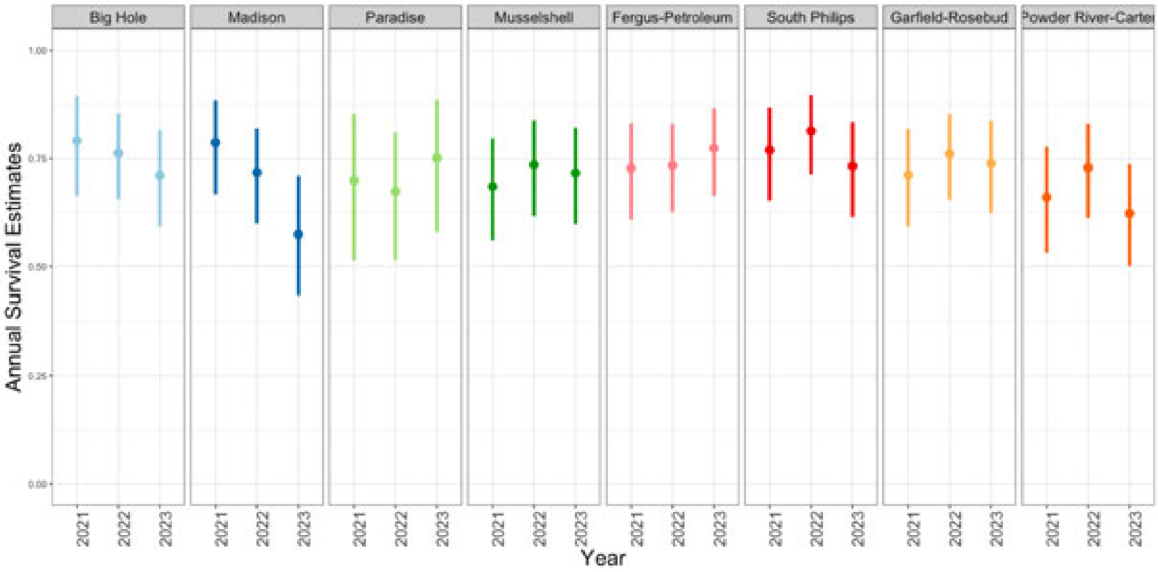


Figure 6. Annual survival probabilities (and 95% credible intervals) estimated from known fate information of collared adult female pronghorn for each study area and biological year (2021 = 01 Jun 2020 – 31 May 2021; 2022 = 01 Jun 2021 – 31 May 2022; 2023 = 01 Jun 2022 – 31 May 2023) in the Montana Pronghorn Movement and Population Ecology Project. The estimated probabilities are the product of each respective biological years' 12 months of survival probabilities for each year and study area.

Table 6. Annual survival probabilities and 95% credible intervals estimated from known fate information of collared adult female pronghorn for each study area and for all study areas (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 area.

Study area	n	Year	Annual survival	95% credible interval 2.5%	95% credible interval 97.5%
Big Hole	61	2021	0.79	0.66	0.90
	61	2022	0.76	0.66	0.85
	47	2023	0.71	0.59	0.82
Madison	60	2021	0.79	0.67	0.88
	50	2022	0.72	0.60	0.82
	35	2023	0.57	0.43	0.71
Paradise	36	2021	0.70	0.51	0.85
	31	2022	0.67	0.52	0.81
	21	2023	0.75	0.58	0.89
Musselshell	60	2021	0.69	0.56	0.80
	60	2022	0.74	0.62	0.84
	45	2023	0.72	0.60	0.82
Fergus-Petroleum	61	2021	0.73	0.61	0.83
	61	2022	0.73	0.63	0.83
	48	2023	0.77	0.66	0.87
South Philips	62	2021	0.77	0.65	0.87
	62	2022	0.81	0.71	0.90
	47	2023	0.73	0.62	0.83
Garfield-Rosebud	61	2021	0.71	0.59	0.82
	60	2022	0.76	0.65	0.85
	49	2023	0.74	0.62	0.84
Powder River-Carter	58	2021	0.66	0.53	0.78
	60	2022	0.73	0.61	0.83
	40	2023	0.62	0.50	0.74

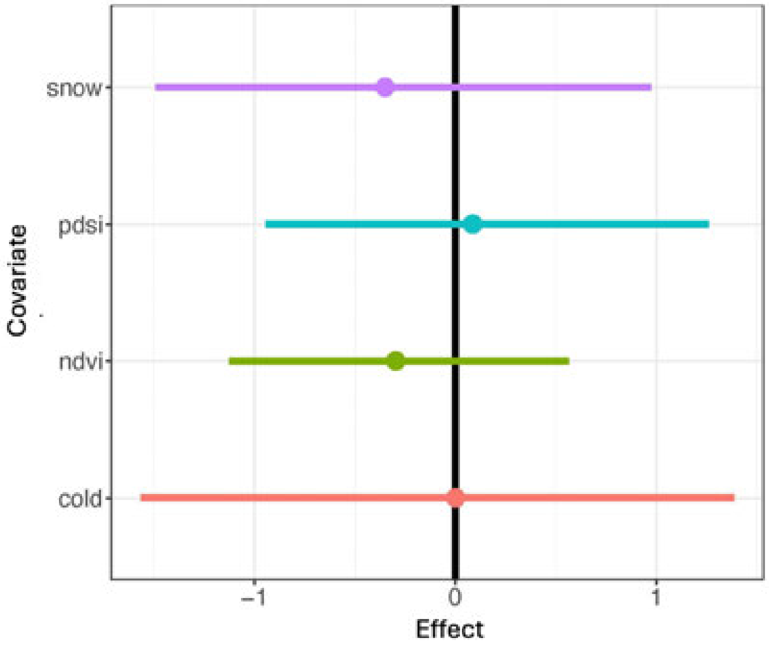


Figure 7: Results demonstrating covariate effects on pronghorn survival. We evaluated the effect the number days colder than −10 degrees Celsius (cold), max percent snow cover (snow), drought severity (PDSI), and greenness as a measure of available nutrition (NDVI). Because all 95% credible intervals overlapped 0 significantly, we did not find any effect of covariates on survival across all 3 years of data.

Objective #1: Delineate seasonal range and migration routes of pronghorn in each study area

1.1 Seasonal ranges and migration routes

We collected 10,946,734 locations from 702 individuals, averaging 15,934 (range: 7 – 38,542) locations and 1.8 (range: 0.0 – 4.4) years of locations collected per individual. This totaled 1,689 animal-years of location data. Movement patterns of individuals were diverse within and across study areas (Figure 8 – 32), with individuals that demonstrate non-migratory behaviors comprising the majority (65 – 94%) of individuals in each study area except the Big Hole (33%), and with migratory behaviors most prevalent in the Big Hole (67% of individuals), Madison (35%), and South Philips (23%) study areas relative to the other study areas (see *Section 1.2 Pronghorn migratory behaviors* 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 routes and seasonal ranges delineated from the collar location data. 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 movement route may exist between Montana and Idaho over Lemhi Pass (Figure 9).

To estimate migration routes (Figure 10 – 31), we first identified migration sequences for each individual-year by plotting net squared displacement (NSD; Bunnefeld et al. 2011, Merkle et al. 2022) curves and mapping movement trajectories for each animal's migratory year, which we selected to span 01 Feb – 31 Jan. We chose 01 Feb as the start of the migratory year to represent when individuals are assumed to be on their winter range for the year. We used the NSD, which uses average daily locations to measure straight-line distances from the first location to each subsequent location in the migratory year, and movement maps to assist in identifying distinct seasonal ranges, departure/arrival timings of spring/fall migrations, and migration distances. For each animal-year, we defined areas where the animal spent the majority of time between the beginning of the migratory year and a spring departure as the initial winter range and between a fall arrival and the end of the migratory year as the final winter range. We defined a spring and fall departure as a distinct, rapid change in NSD that stabilized when the animal arrived at its first summer range or final winter range, respectively. We selected departure and arrival dates based on the collar location that occurred immediately prior to the first and immediately after the last collar location of the animal's migration trajectory, respectively. We defined a summer range as an area where the animal spent >21 days and was >10 km from the winter range, or other summer ranges if the animal visited multiple summer ranges. Thus, if an animal departed from its winter range to an area that was ≤10 km away and spent >21 days, this area was considered part of its winter range. If an animal departed from its winter range to an area that was >10 km away but spent ≤21 days, the area was considered a stop-over site and not a distinct range, unless that area was also within 10 km from a subsequent area where the animal spent >21 days, in which case it was considered part of that subsequent area and, therefore, summer range. We chose the duration threshold based on other pronghorn movement studies reporting approximate average stopover durations ranging 10 – 17 days (Seidler et al. 2015, Jakes et al. 2018*a*). Our relatively low distance threshold of 10 km was similar to the 15 km threshold used by Kolar et al. (2011). To measure distances between ranges, we visually examined 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 and summer ranges <10 km apart based on straight-line distance). We used the date of departure and arrival for each spring and fall migratory period to represent migration sequences for each animal's migratory year. We identified migration sequences only for animal-years with at least 11 months of data for each migratory year.

Last, we 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). In general, we applied a 4-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 routes 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 11 – 32), 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. We used these fixed calendar dates to generally represent biologically meaningful periods for pronghorn that encompass the spring migration and calving, movements on summer range, fall migration, and movements on winter range, respectively.

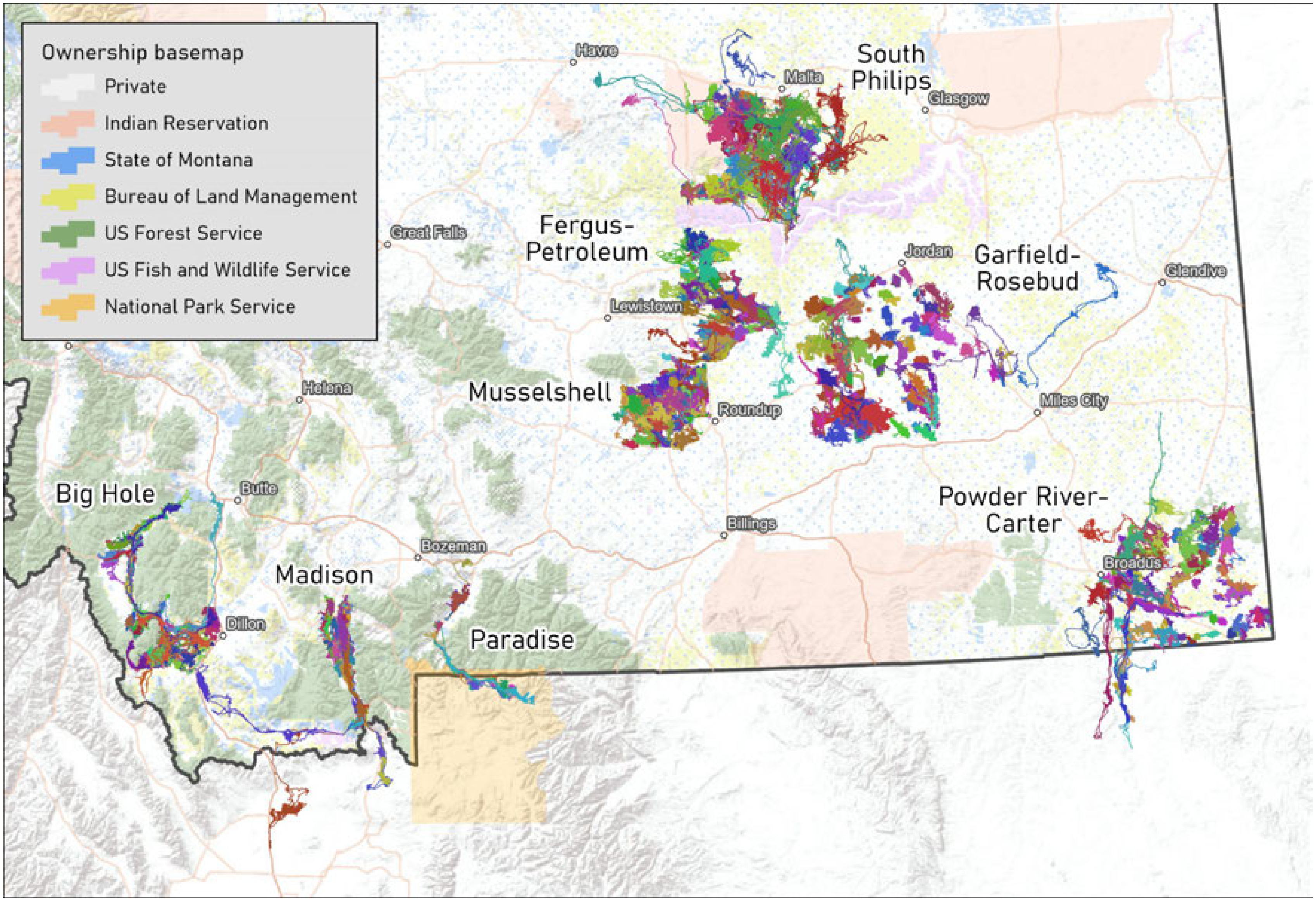


Figure 8. Movements of collared adult female pronghorn (colored by individual) in each study area for the Montana Pronghorn Movement and Population Ecology Project from January 2020 – June 2023 (January 2019 – June 2023 in Madison).

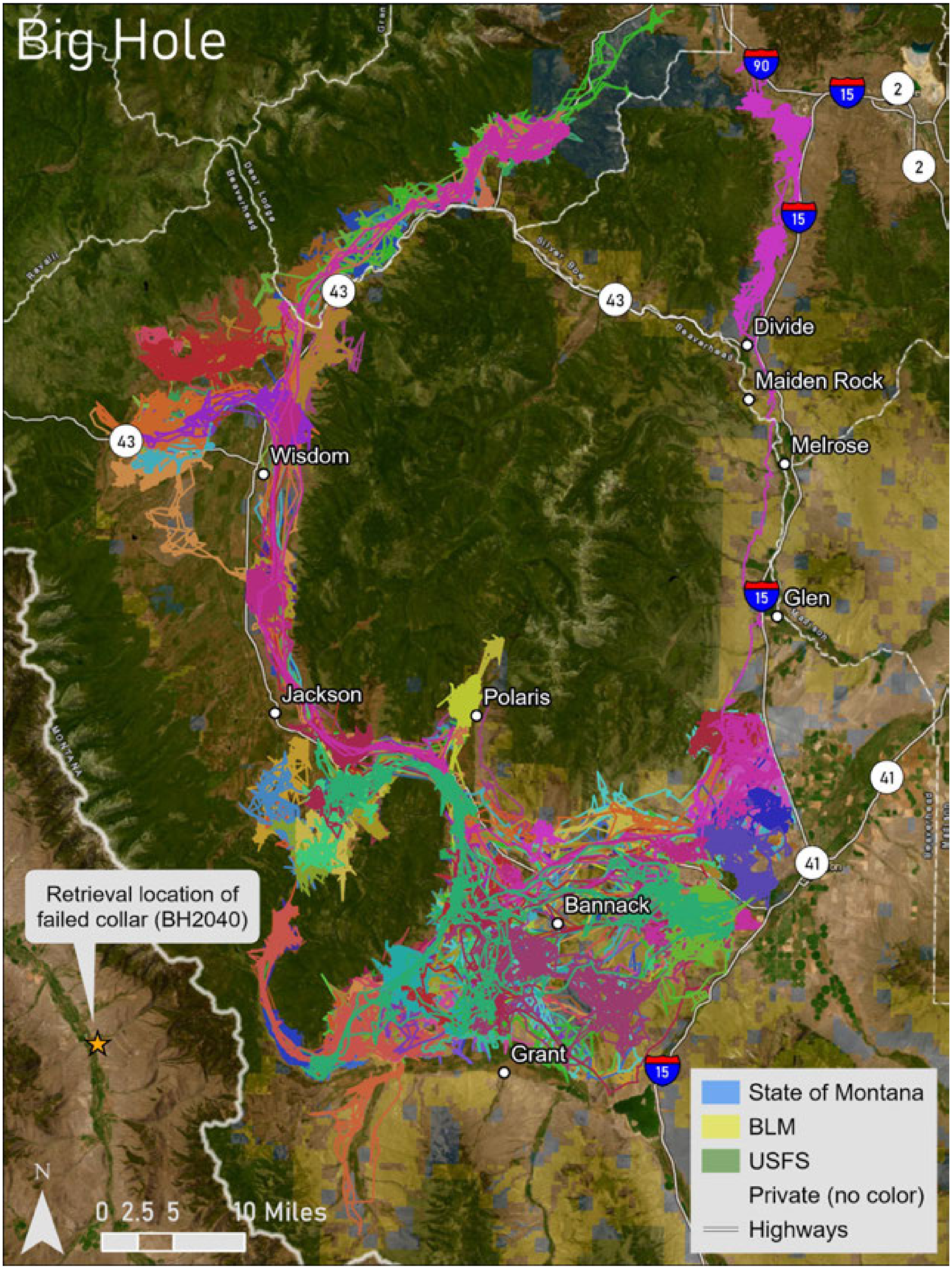


Figure 9. Movements of collared adult female pronghorn (colored by individual) in the Big Hole study area for the Montana Pronghorn Movement and Population Ecology Project from January 2020 to June 2023. See the text for a description related to the location of the failed collar in Idaho.

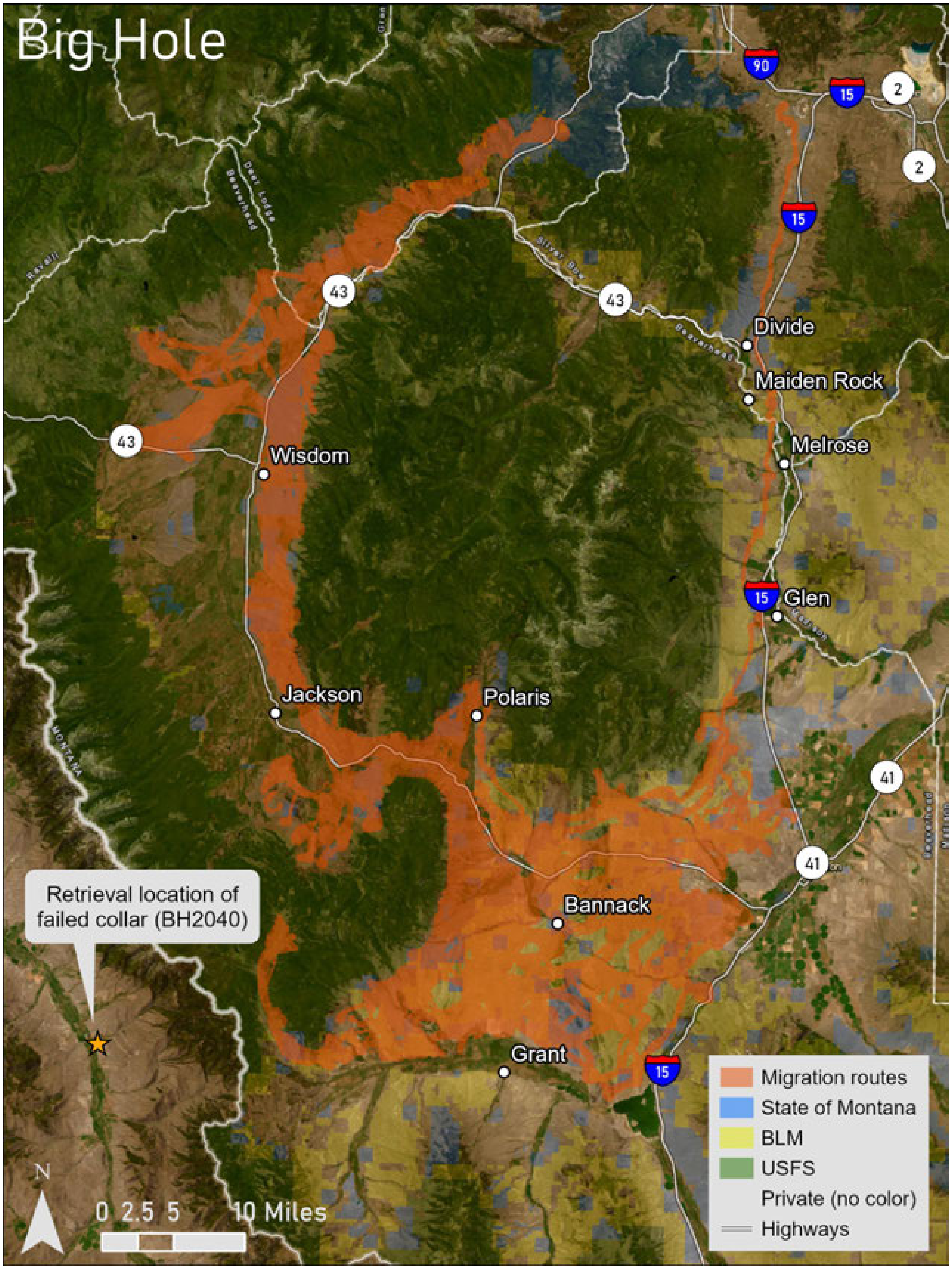


Figure 10. Estimated migration routes of migrant collared adult female pronghorn in the Big Hole study area for the Montana Pronghorn Movement and Population Ecology Project. Migration routes represent areas used by ≥1 migrant during spring and/or fall migration periods from January 2020 to June 2023. See the text for a description related to the location of the failed collar in Idaho.

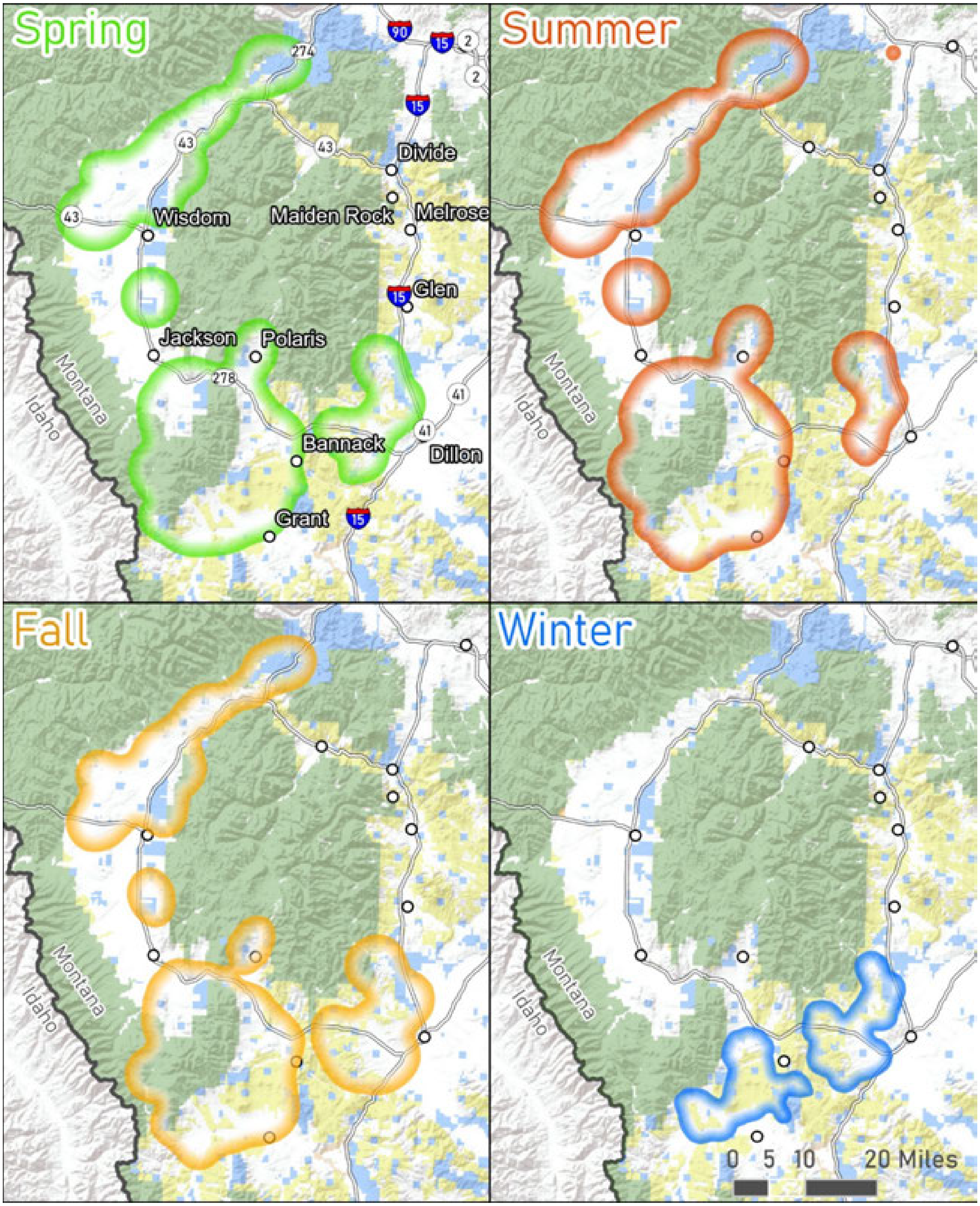


Figure 11. Seasonal ranges of collared adult female pronghorn in the Big Hole study area for the Montana Pronghorn Movement and Population Ecology Project from January 2020 to June 2023. Spring: Apr 1 – Jun 30; Summer: Jul 1 – Aug 31; Fall: Sep 1 – Nov 30; Winter: Dec 1 – Mar 31.

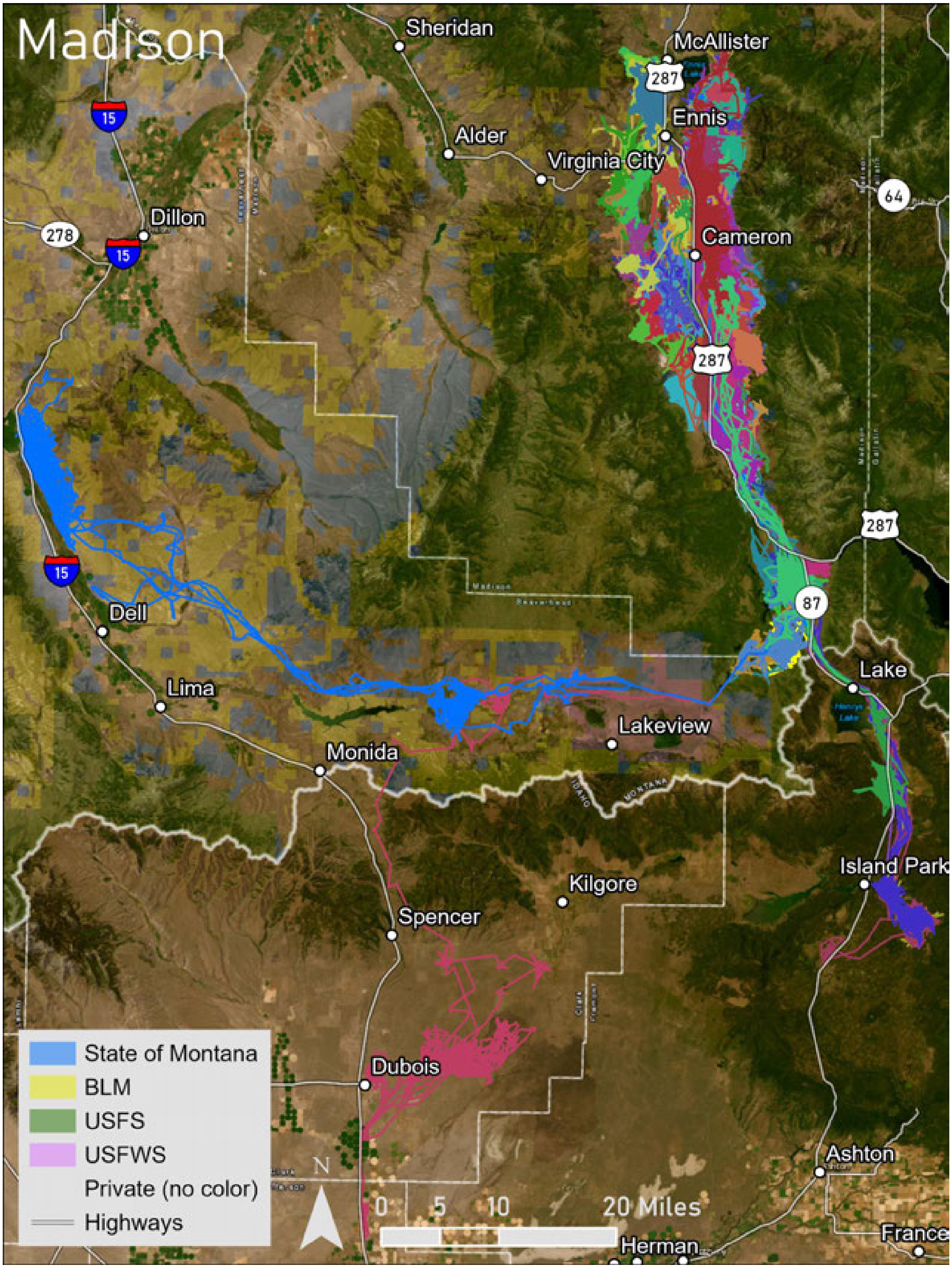


Figure 12. Movements of collared adult female pronghorn (colored by individual) in the Madison study area for the Montana Pronghorn Movement and Population Ecology Project from January 2019 to June 2023.

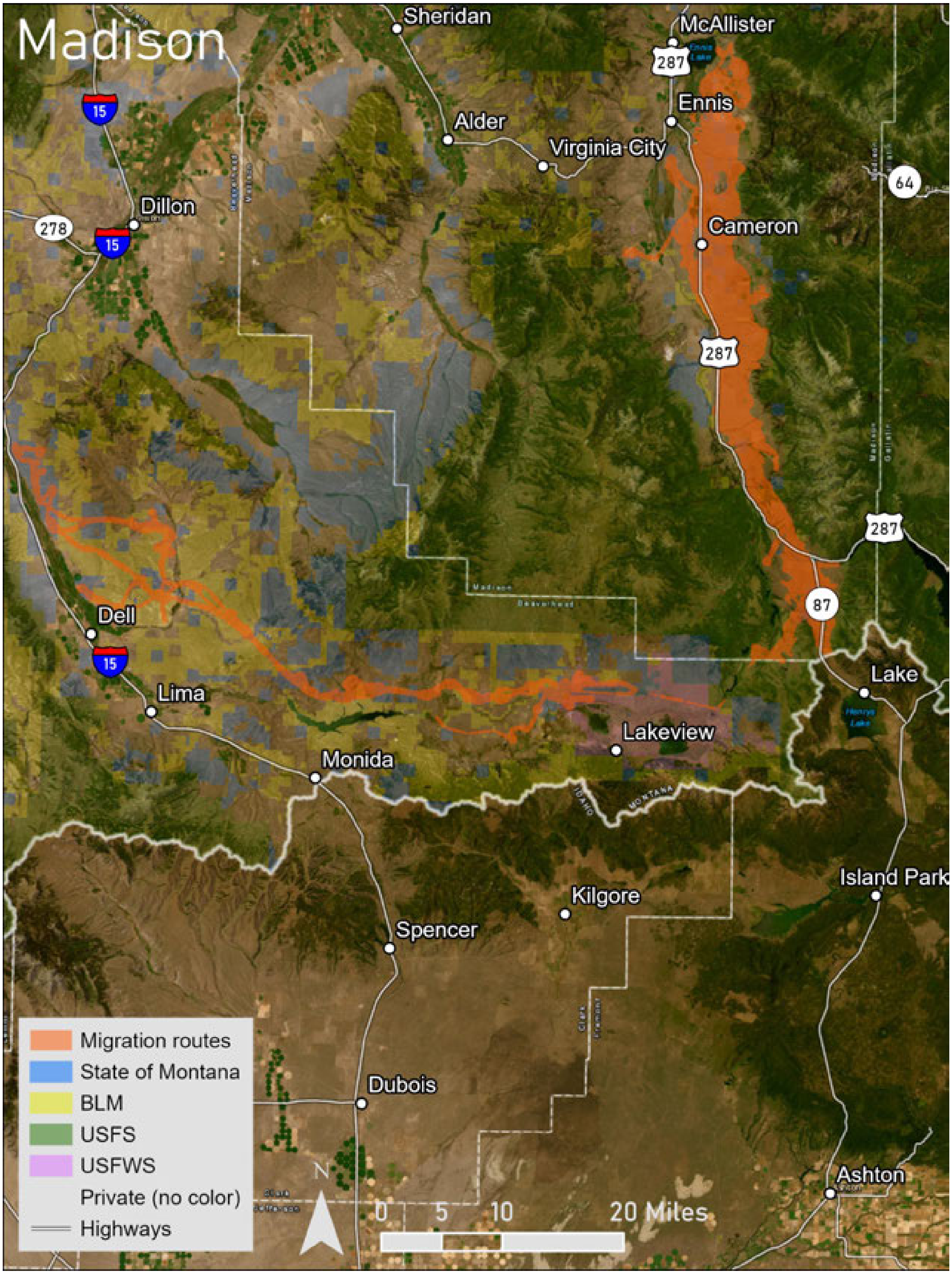


Figure 13. Estimated migration routes of migrant collared adult female pronghorn in the Madison study area for the Montana Pronghorn Movement and Population Ecology Project. Migration routes represent areas used by ≥1 migrant during spring and/or fall migration periods from January 2019 to June 2023 and are clipped to Montana only.

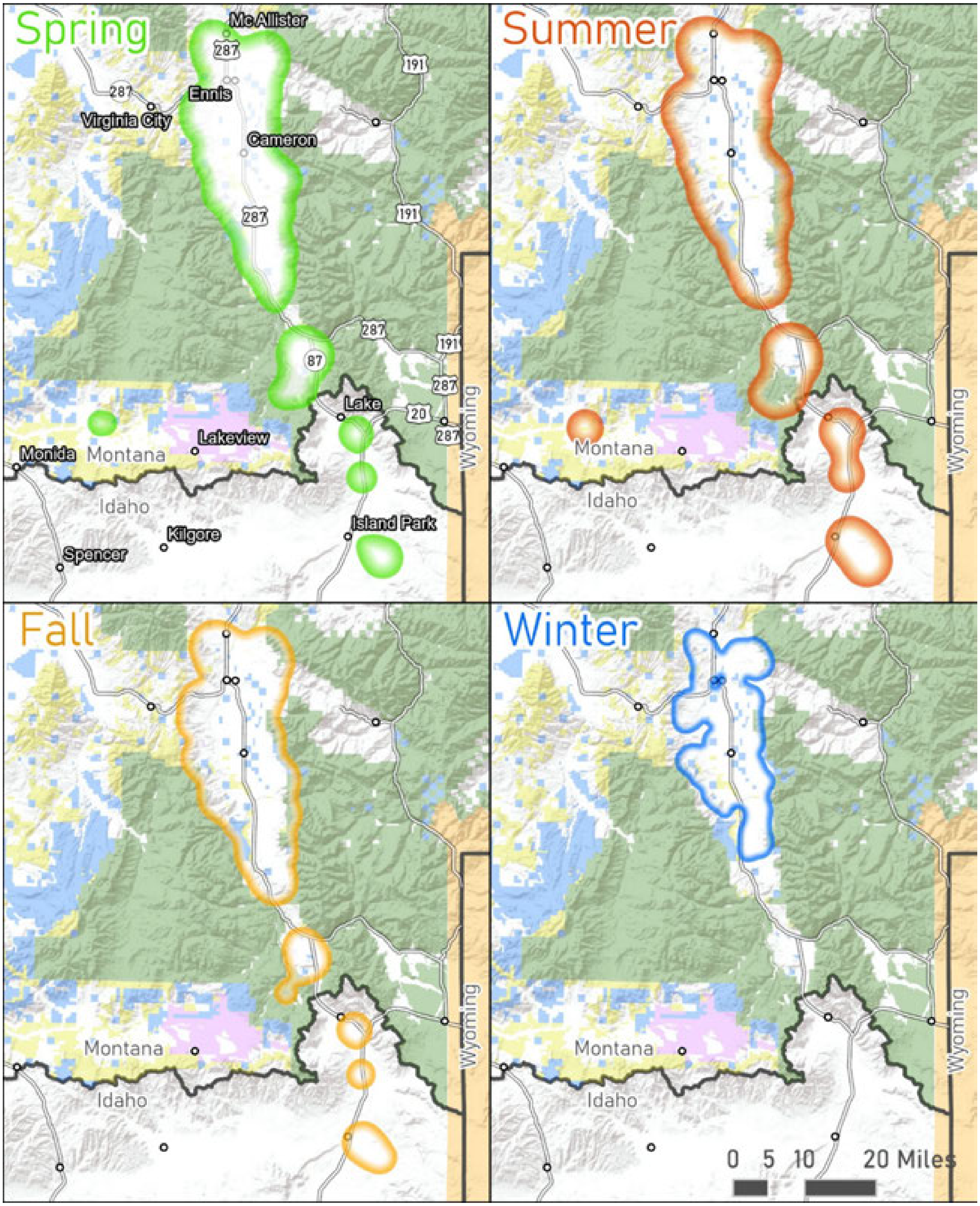


Figure 14. Seasonal ranges of collared adult female pronghorn in the Madison study area for the Montana Pronghorn Movement and Population Ecology Project from January 2019 to June 2023. Spring: Apr 1 – Jun 30; Summer: Jul 1 – Aug 31; Fall: Sep 1 – Nov 30; Winter: Dec 1 – Mar 31.

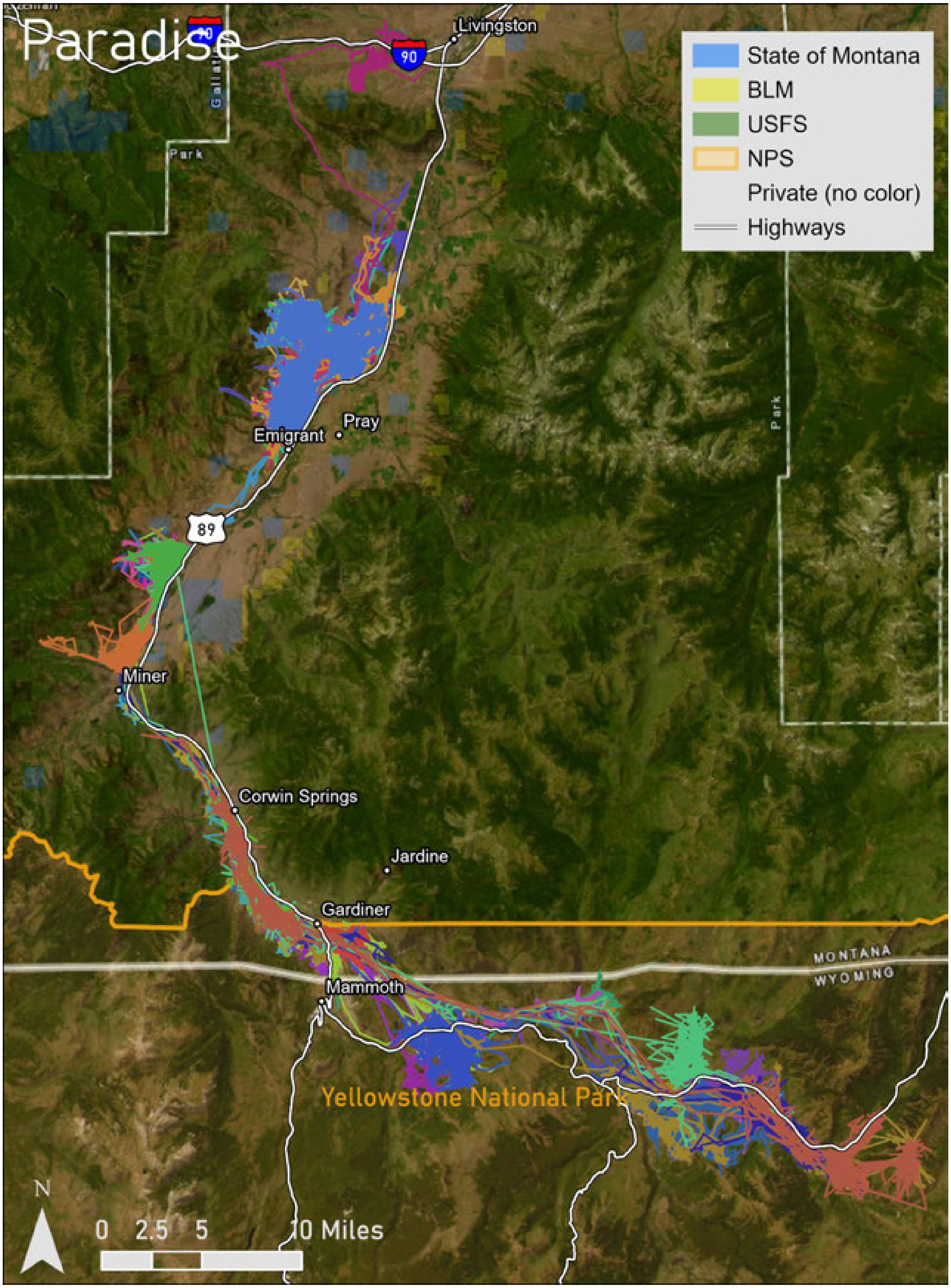


Figure 15. Movements of collared adult female pronghorn (colored by individual) in the Paradise study area for the Montana Pronghorn Movement and Population Ecology Project from January 2020 to June 2023.

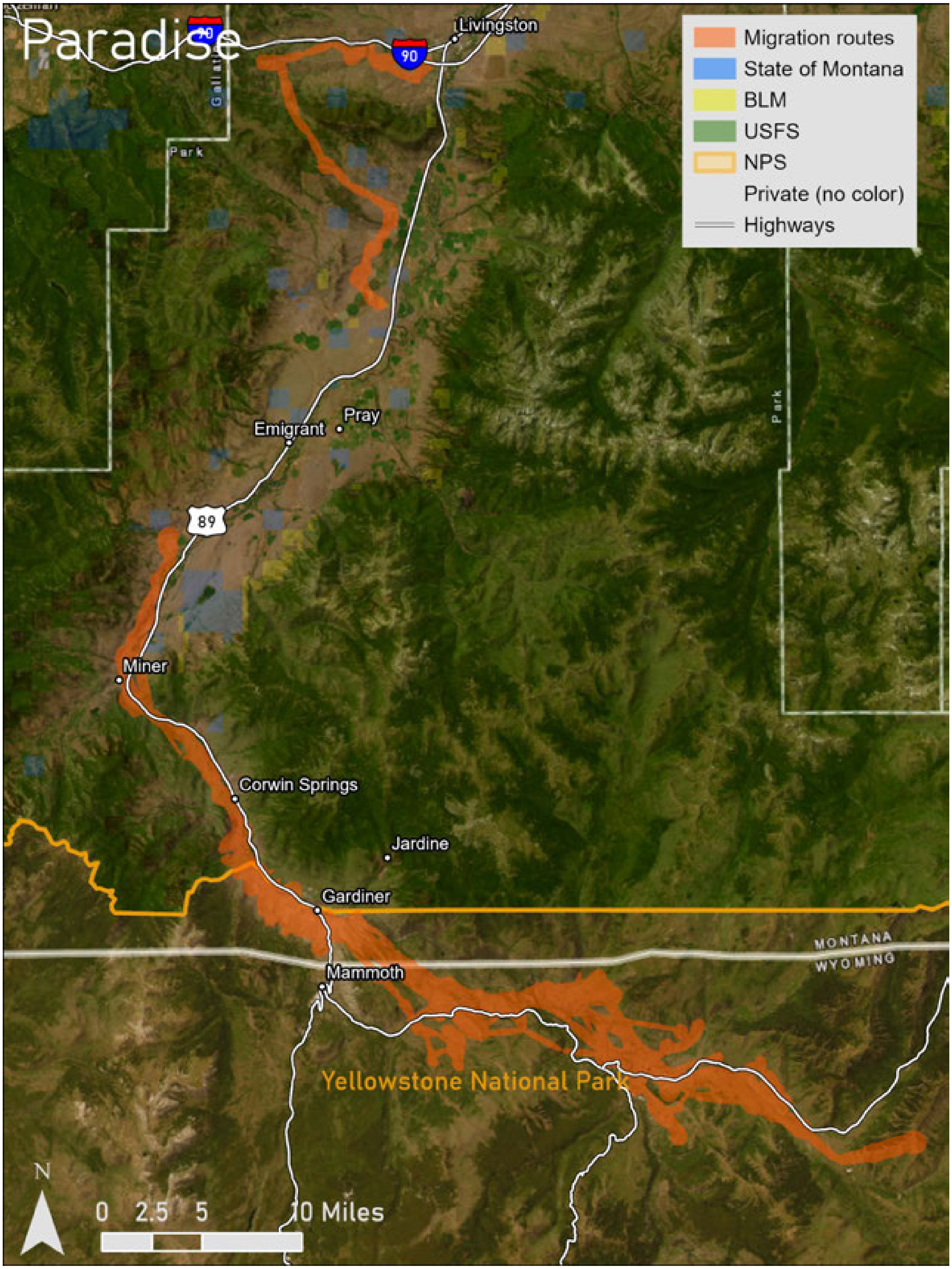


Figure 16. Estimated migration routes of migrant collared adult female pronghorn in the Paradise study area for the Montana Pronghorn Movement and Population Ecology Project. Migration routes represent areas used by ≥1 migrant during spring and/or fall migration periods from January 2020 to June 2023.

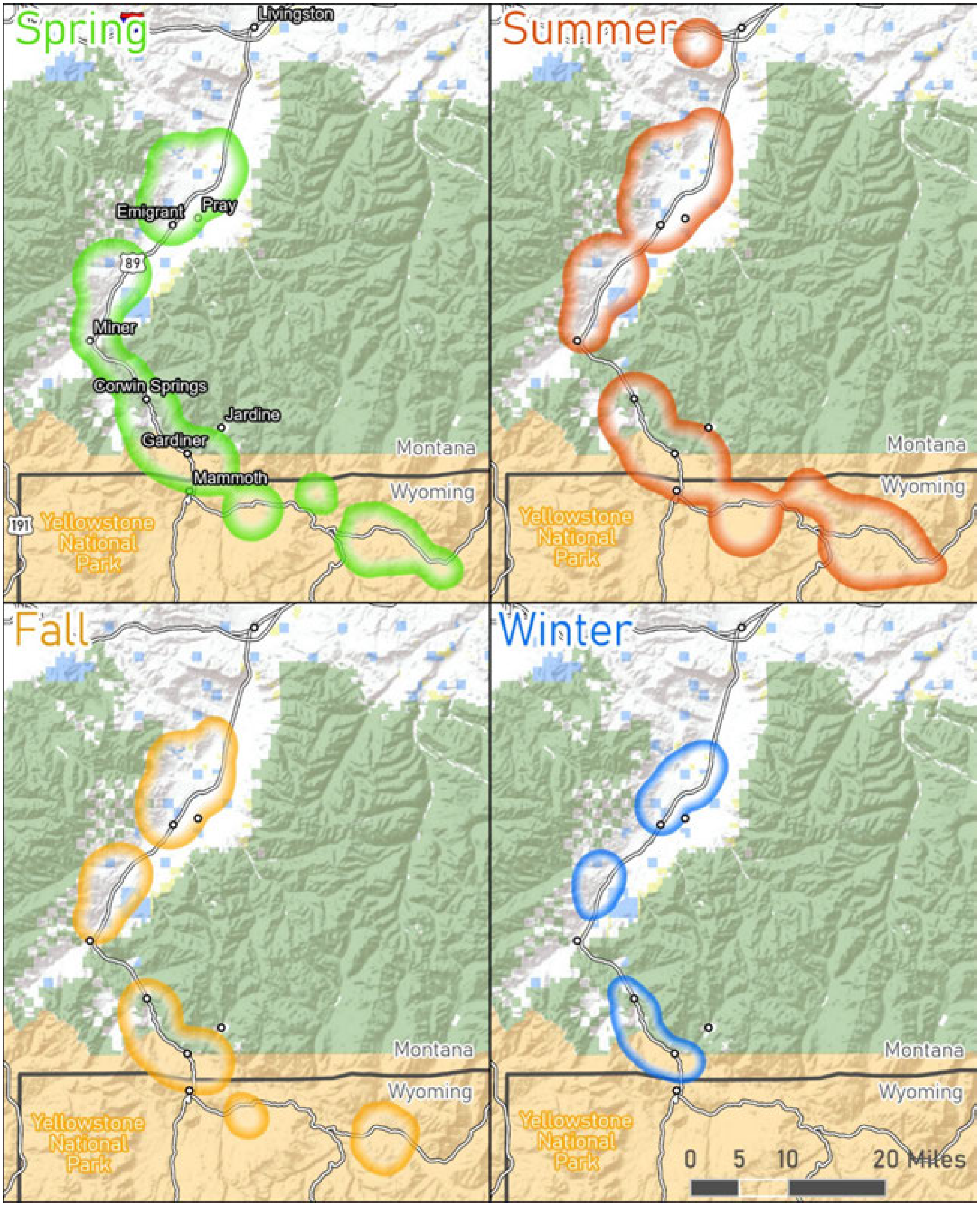


Figure 17. Seasonal ranges of collared adult female pronghorn in the Paradise study area for the Montana Pronghorn Movement and Population Ecology Project from January 2020 to June 2023. Spring: Apr 1 – Jun 30; Summer: Jul 1 – Aug 31; Fall: Sep 1 – Nov 30; Winter: Dec 1 – Mar 31.

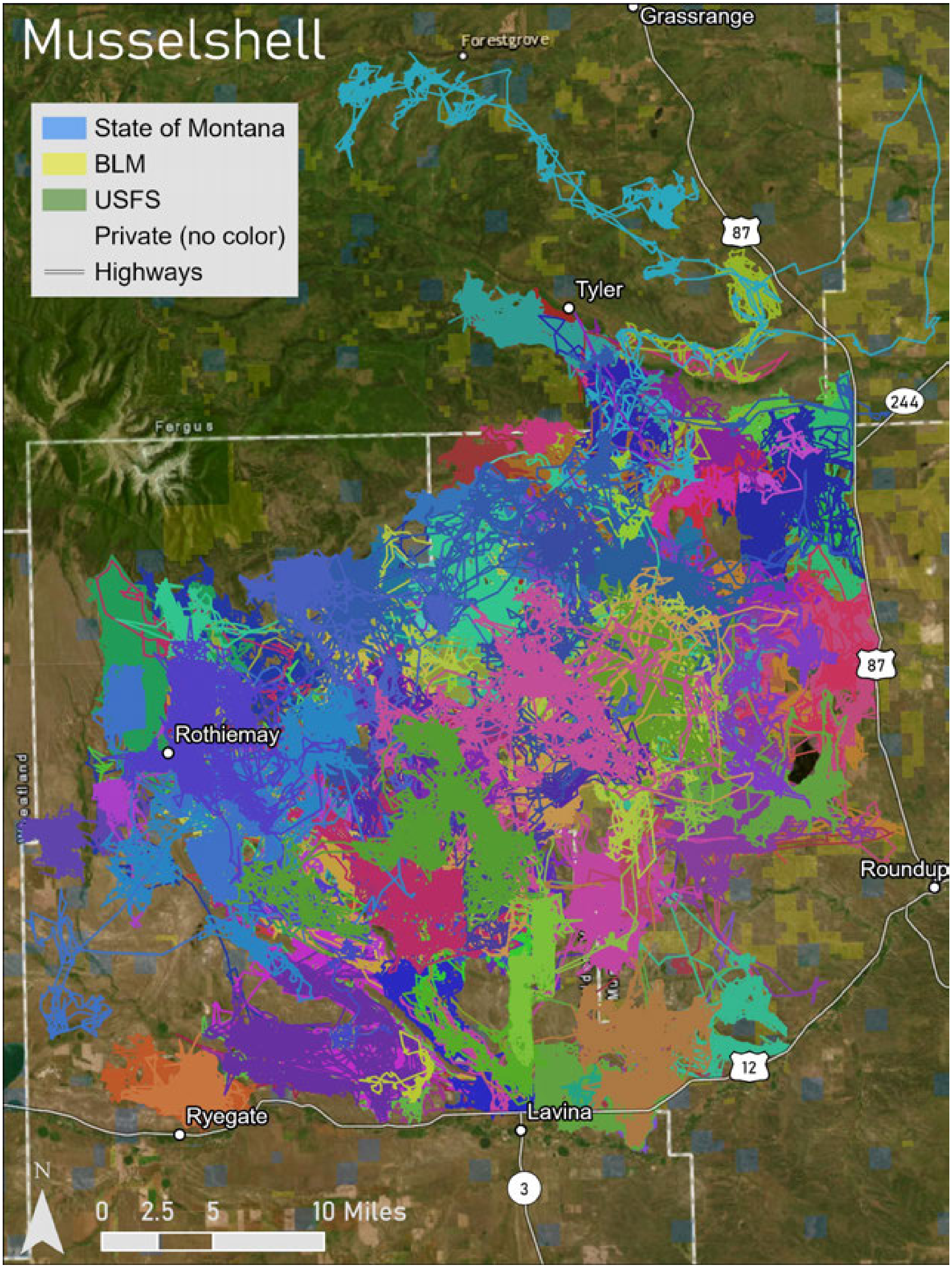


Figure 18. Movements of collared adult female pronghorn (colored by individual) in the Musselshell study area for the Montana Pronghorn Movement and Population Ecology Project from January 2020 to June 2023.

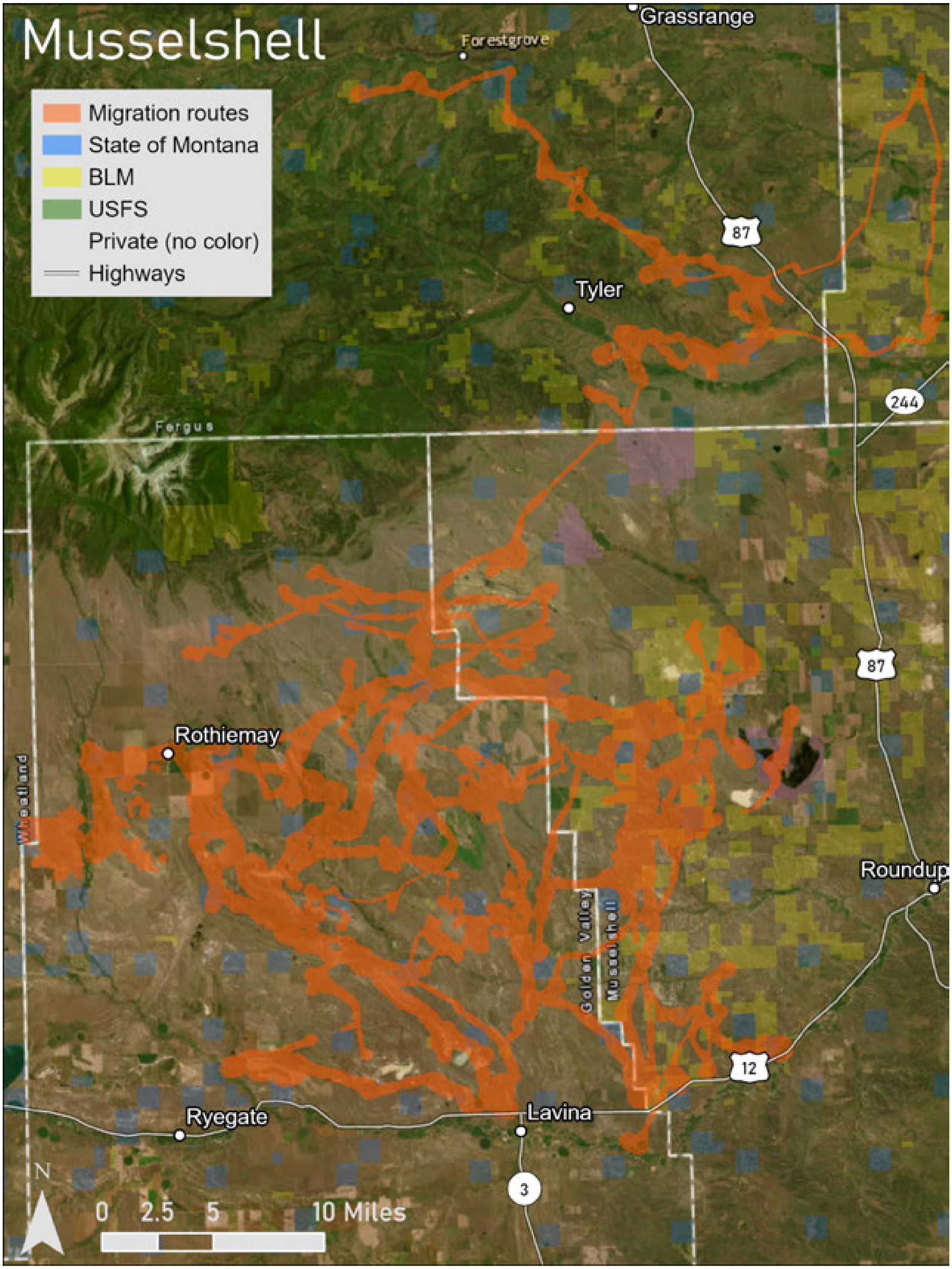


Figure 19. Estimated migration routes of migrant collared adult female pronghorn in the Musselshell study area for the Montana Pronghorn Movement and Population Ecology Project. Migration routes represent areas used by ≥1 migrant during spring and/or fall migration periods from January 2020 to June 2023.

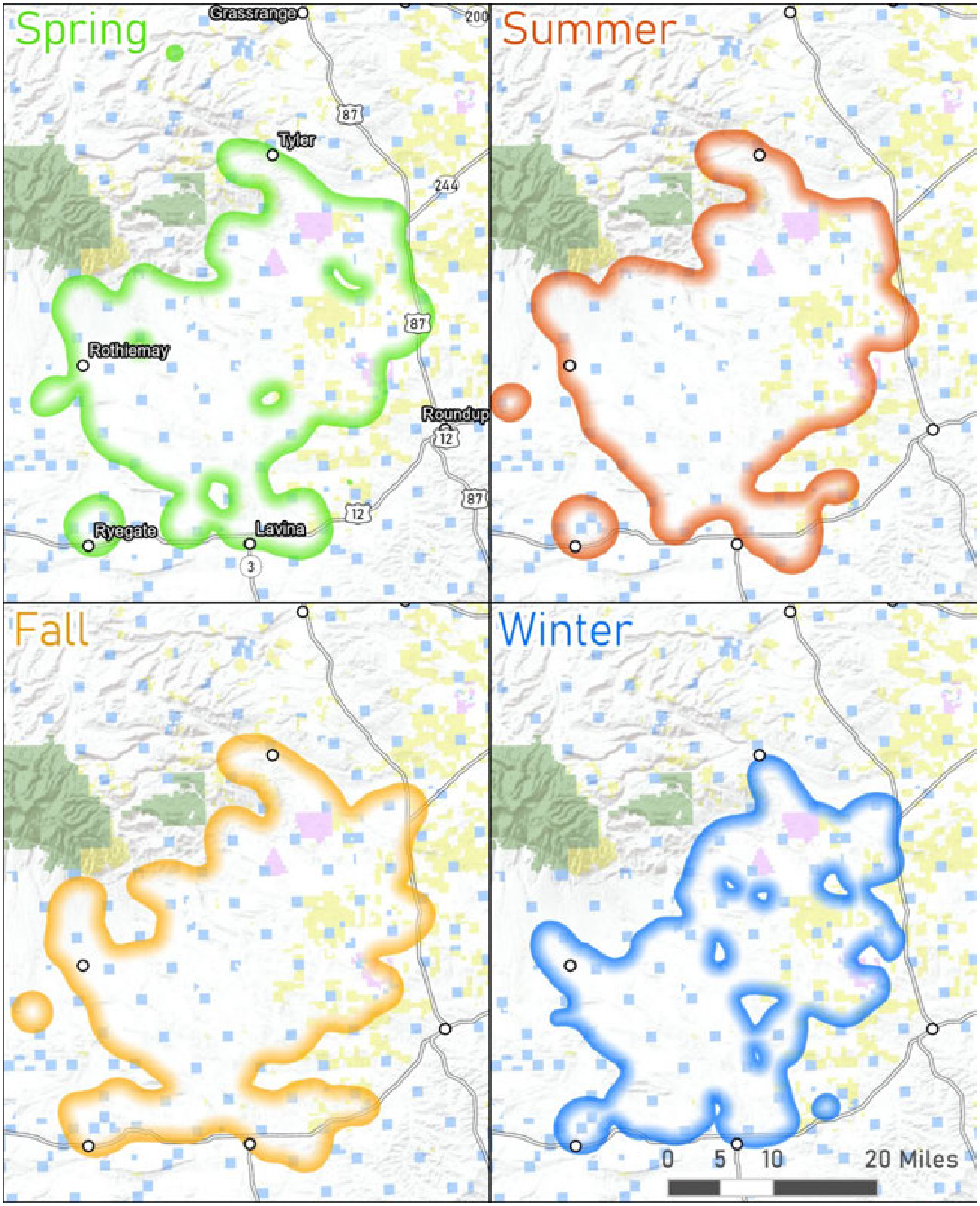


Figure 20. Seasonal ranges of collared adult female pronghorn in the Musselshell study area for the Montana Pronghorn Movement and Population Ecology Project from January 2020 to June 2023. Spring: Apr 1 – Jun 30; Summer: Jul 1 – Aug 31; Fall: Sep 1 – Nov 30; Winter: Dec 1 – Mar 31.

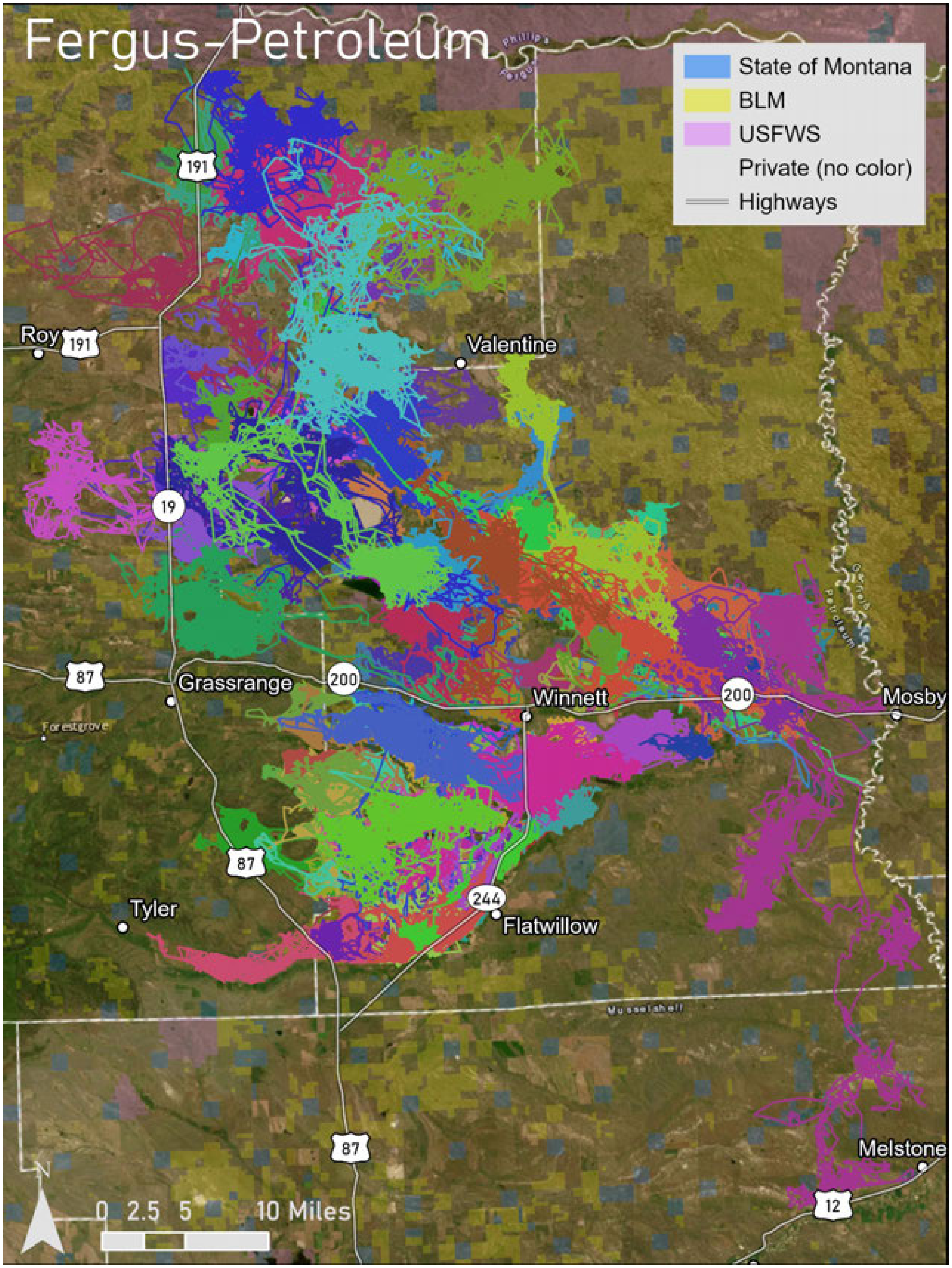


Figure 21. Movements of collared adult female pronghorn (colored by individual) in the Fergus-Petroleum study area for the Montana Pronghorn Movement and Population Ecology Project from January 2020 to June 2023.

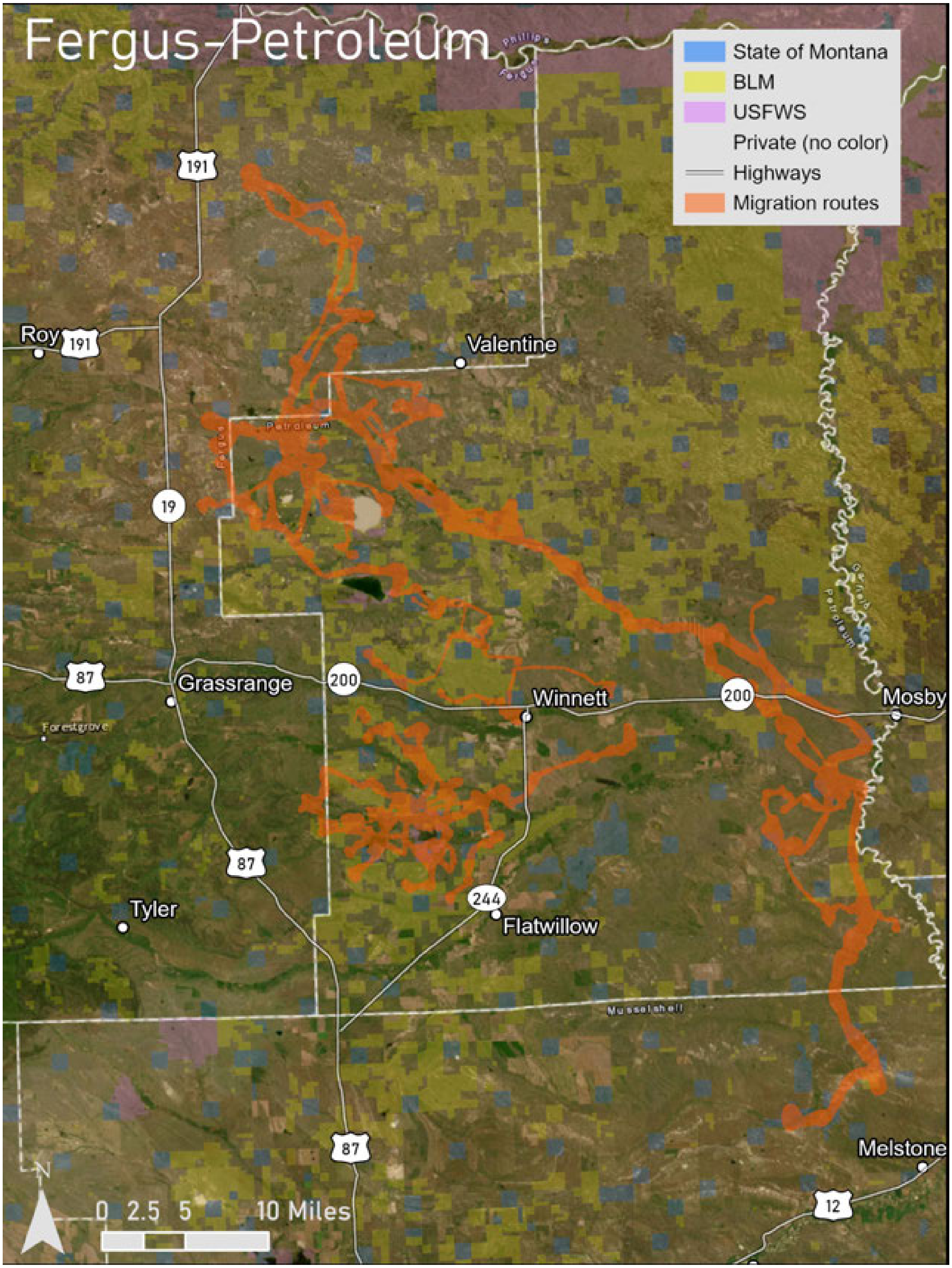


Figure 22. Estimated migration routes of migrant collared adult female pronghorn in the Fergus-Petroleum study area for the Montana Pronghorn Movement and Population Ecology Project. Migration routes represent areas used by ≥1 migrant during spring and/or fall migration periods from January 2020 to June 2023.

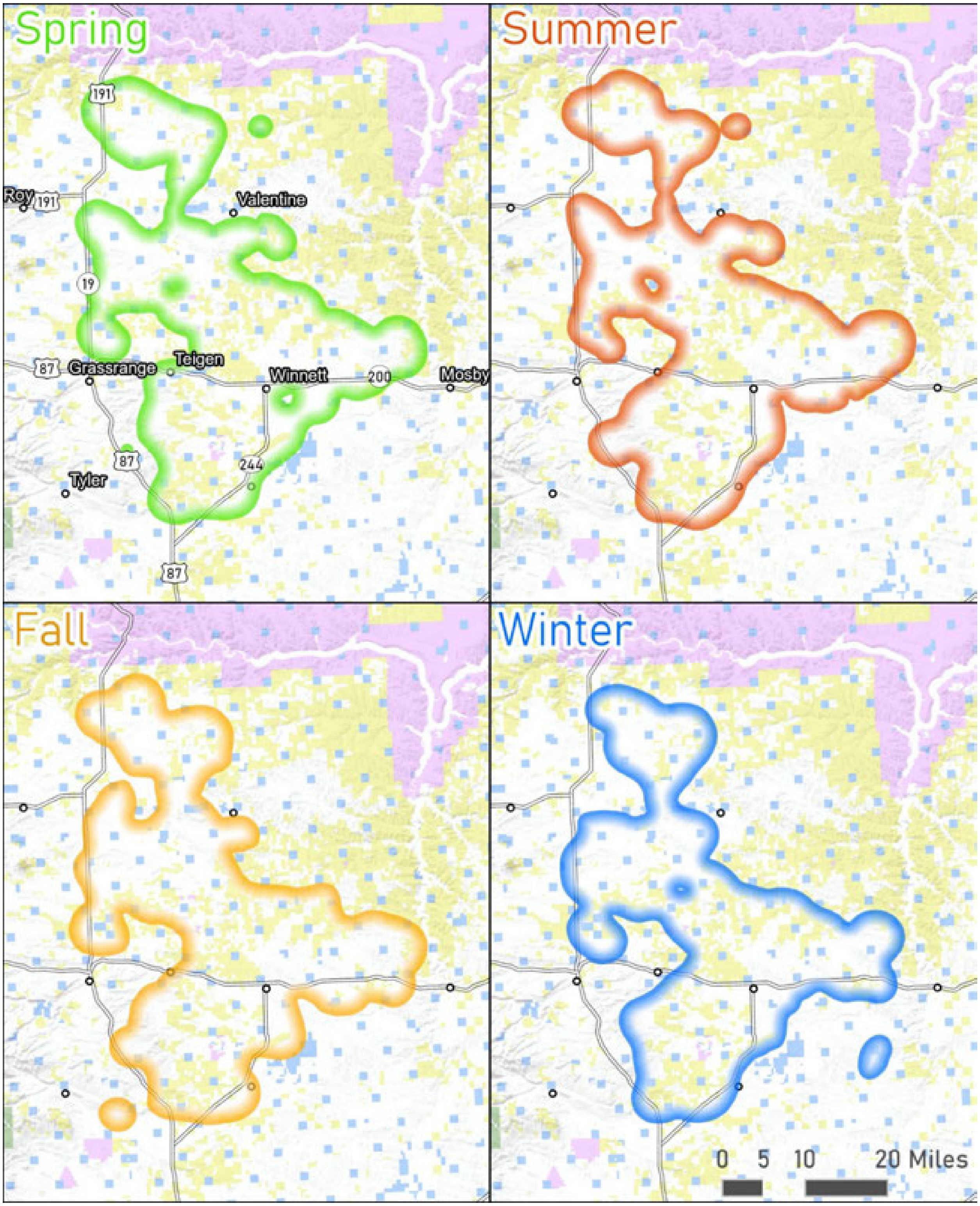


Figure 23. Seasonal ranges of collared adult female pronghorn in the Fergus-Petroleum area for the Montana Pronghorn Movement and Population Ecology Project from January 2020 to June 2023. Spring: Apr 1 – Jun 30; Summer: Jul 1 – Aug 31; Fall: Sep 1 – Nov 30; Winter: Dec 1 – Mar 31.

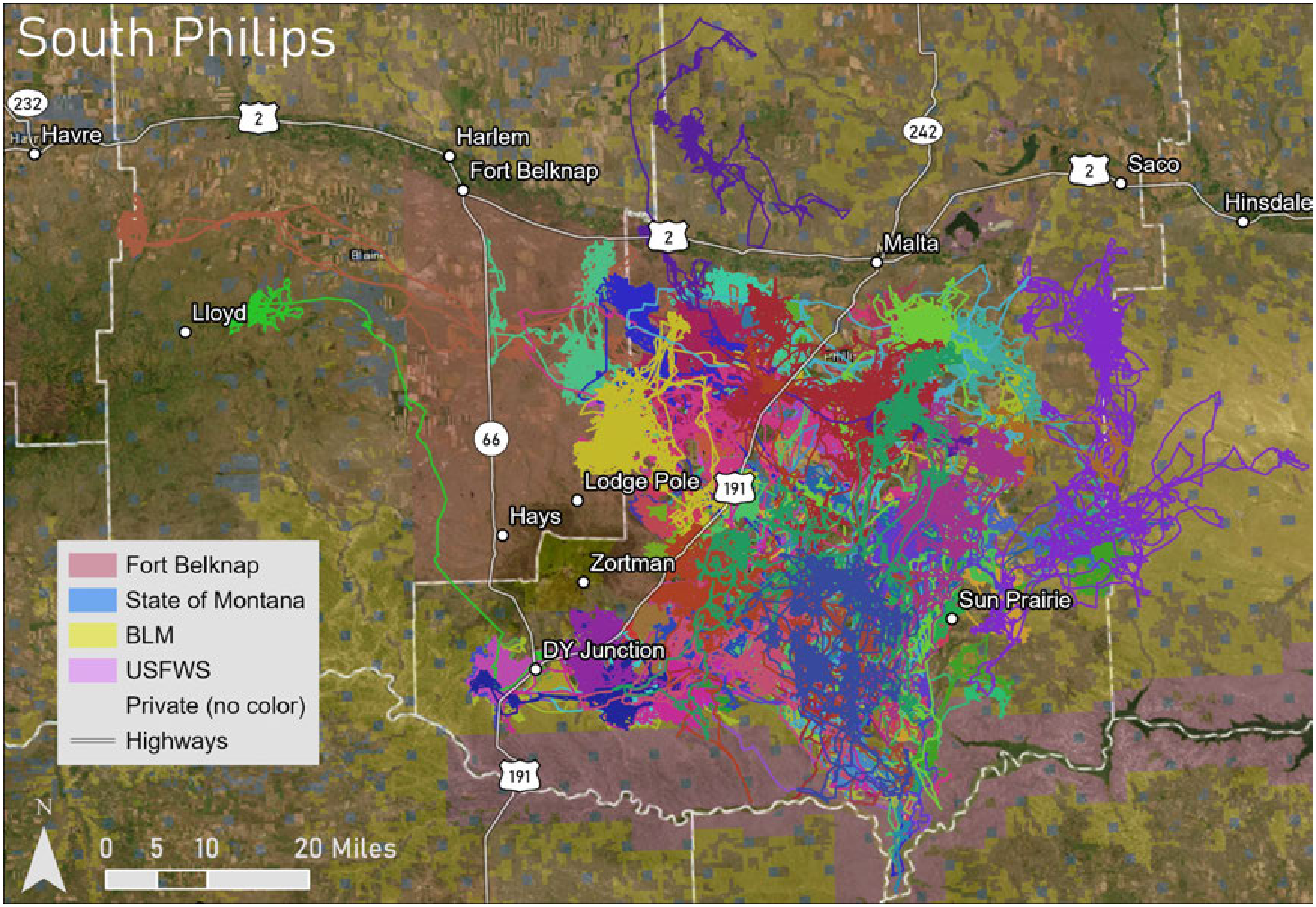


Figure 24. Movements of collared adult female pronghorn (colored by individual) in the South Philips study area for the Montana Pronghorn Movement and Population Ecology Project from January 2020 to June 2023.

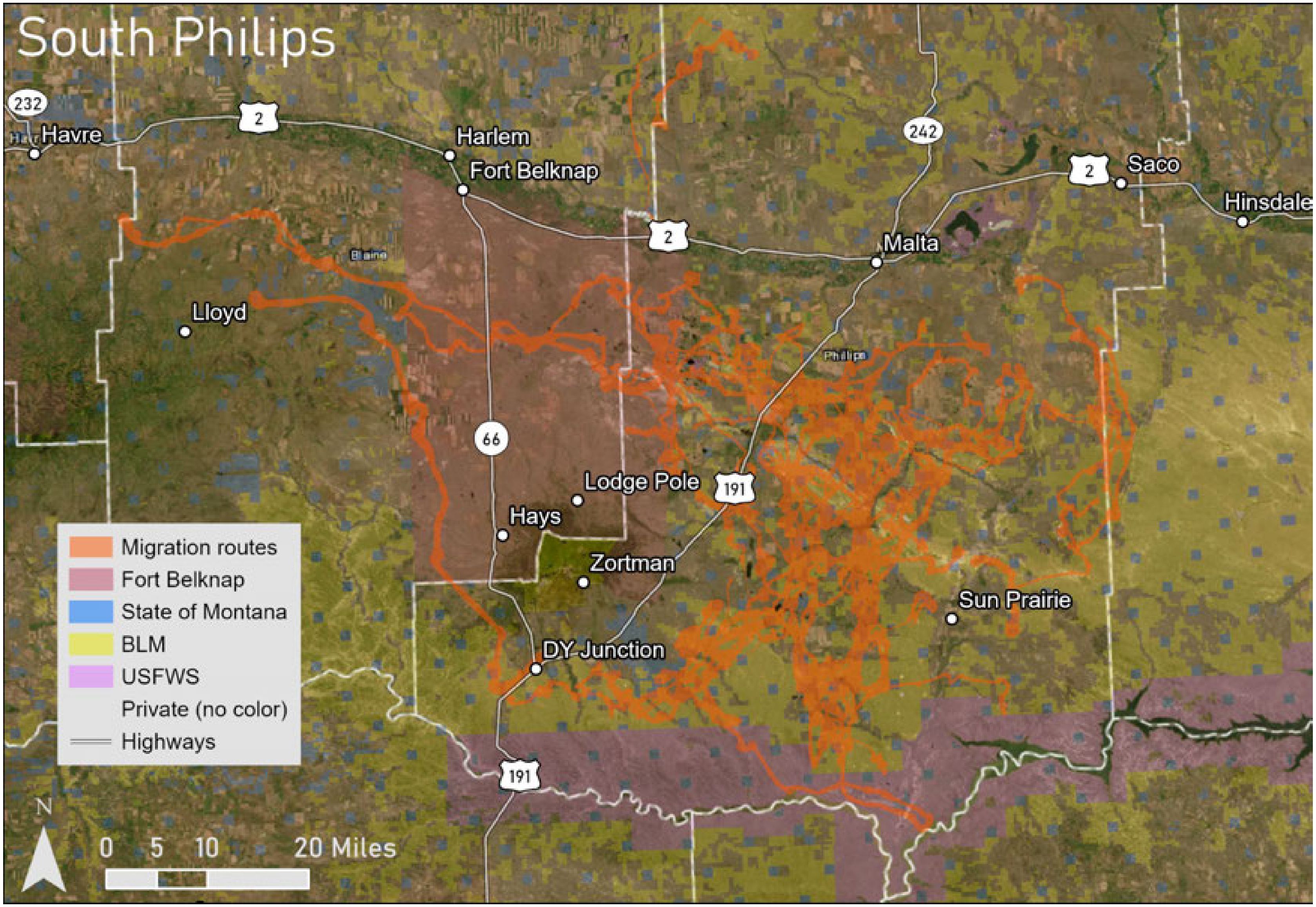


Figure 25. Estimated migration routes of migrant collared adult female pronghorn in the South Philips study area for the Montana Pronghorn Movement and Population Ecology Project. Migration routes represent areas used by ≥1 migrant during spring and/or fall migration periods from January 2020 to June 2023.

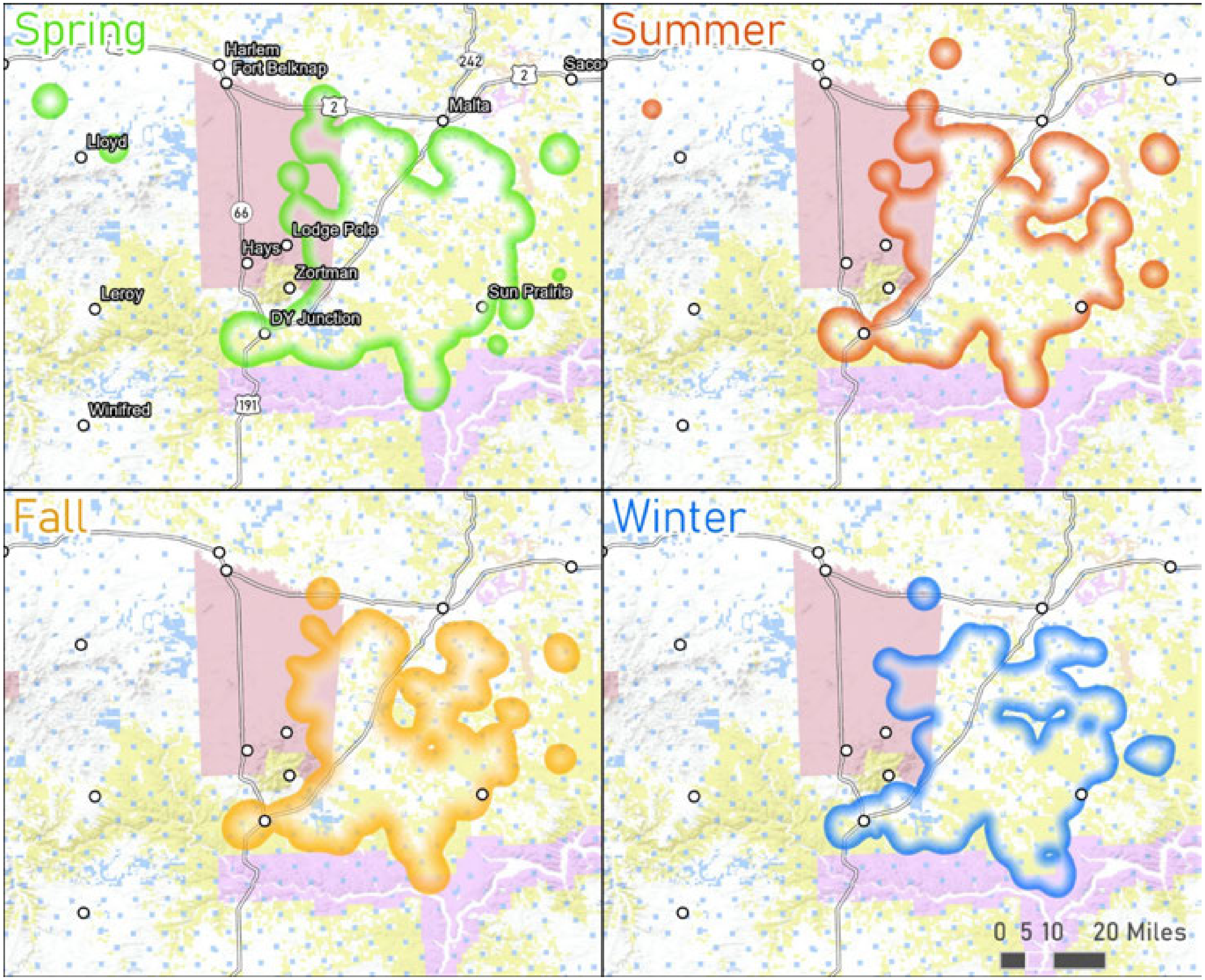


Figure 26. Seasonal ranges of collared adult female pronghorn in the South Philips area for the Montana Pronghorn Movement and Population Ecology Project from January 2020 to June 2023. Spring: Apr 1 – Jun 30; Summer: Jul 1 – Aug 31; Fall: Sep 1 – Nov 30; Winter: Dec 1 – Mar 31.

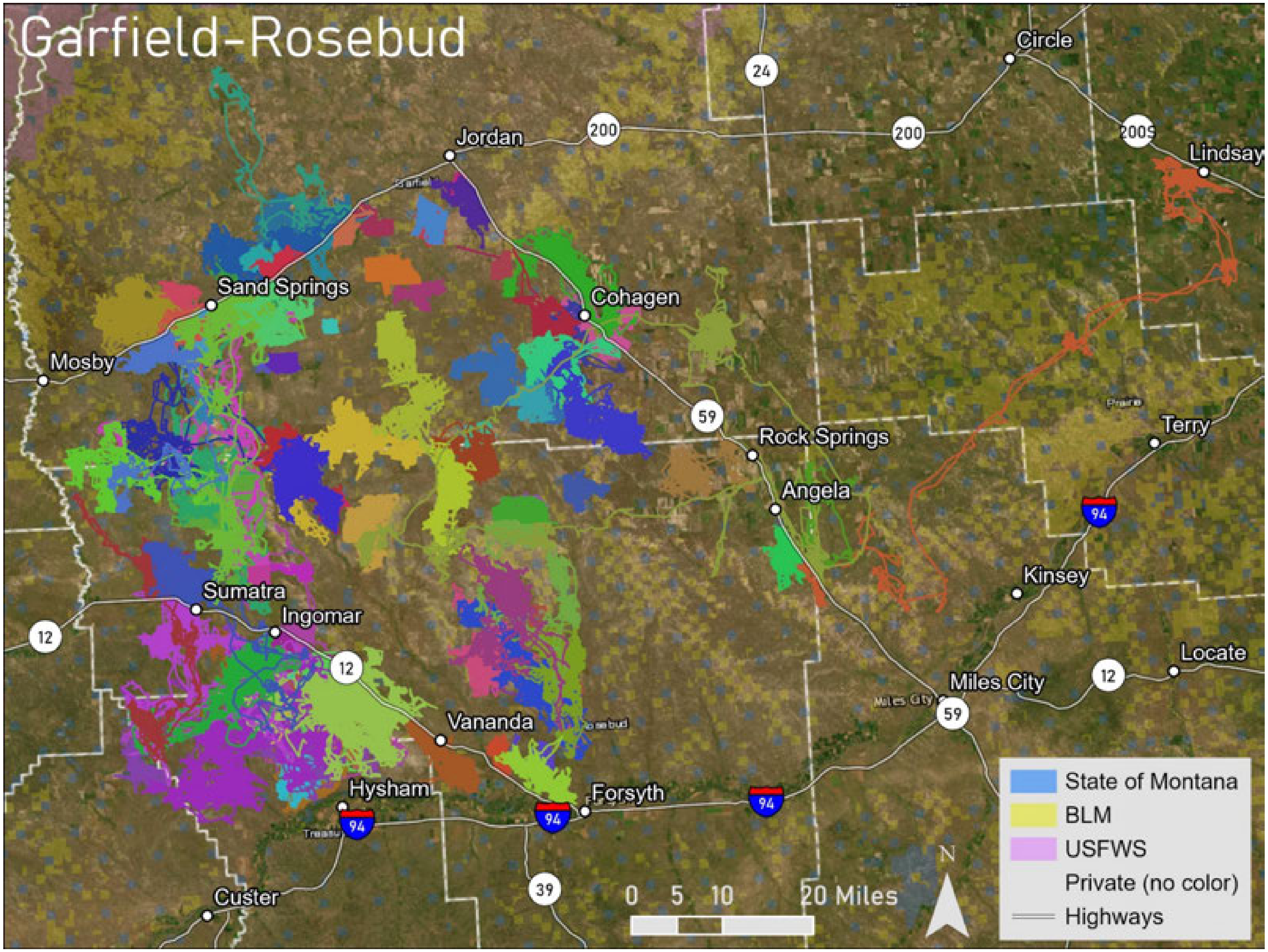


Figure 27. Movements of collared adult female pronghorn (colored by individual) in the Garfield-Rosebud study area for the Montana Pronghorn Movement and Population Ecology Project from January 2020 to June 2023.

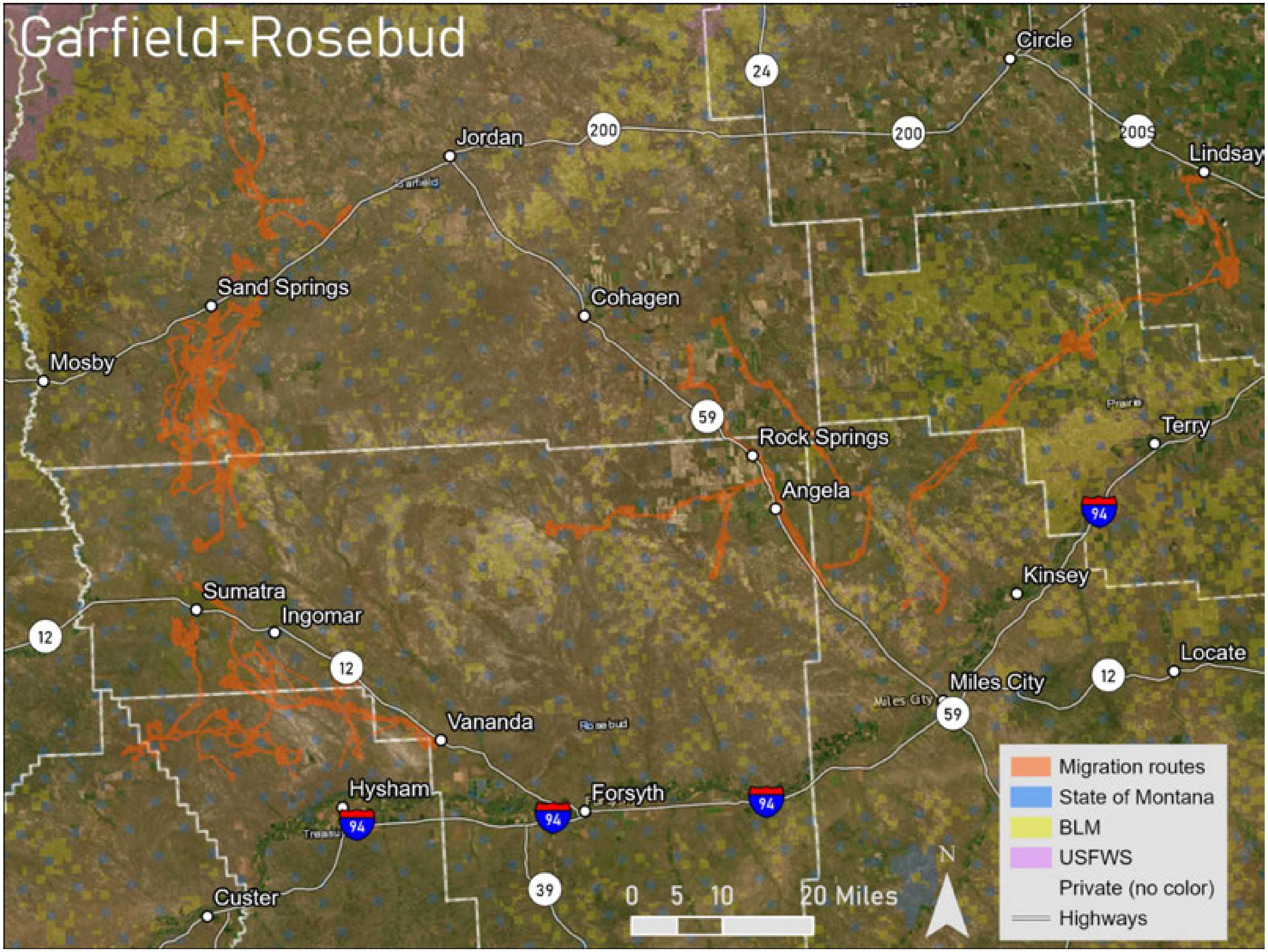


Figure 28. Estimated migration routes of migrant collared adult female pronghorn in the Garfield-Rosebud study area for the Montana Pronghorn Movement and Population Ecology Project. Migration routes represent areas used by ≥1 migrant during spring and/or fall migration periods from January 2020 to June 2023.

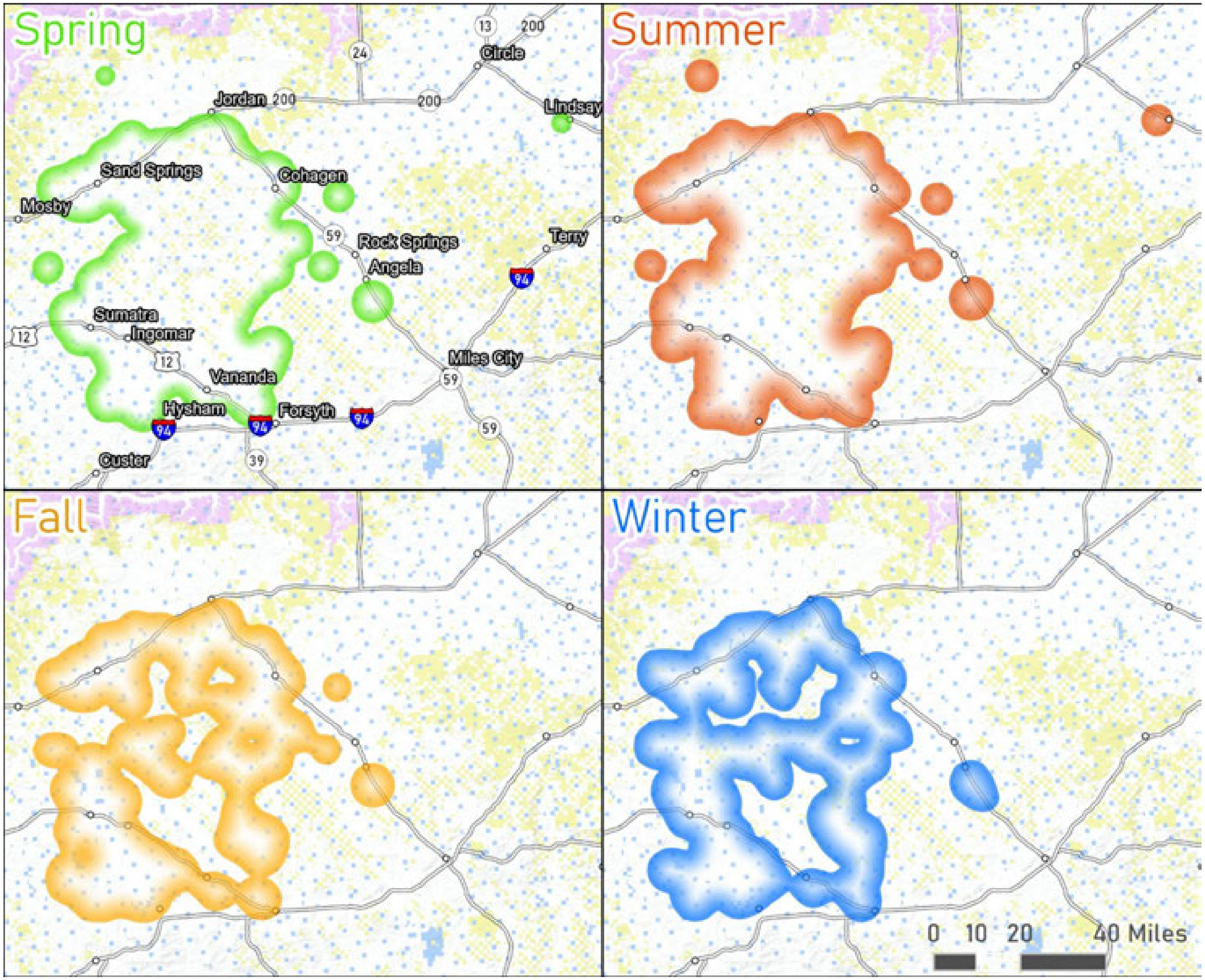


Figure 29. Seasonal ranges of collared adult female pronghorn in the Garfield-Rosebud area for the Montana Pronghorn Movement and Population Ecology Project from January 2020 to June 2023. Spring: Apr 1 – Jun 30; Summer: Jul 1 – Aug 31; Fall: Sep 1 – Nov 30; Winter: Dec 1 – Mar 31.

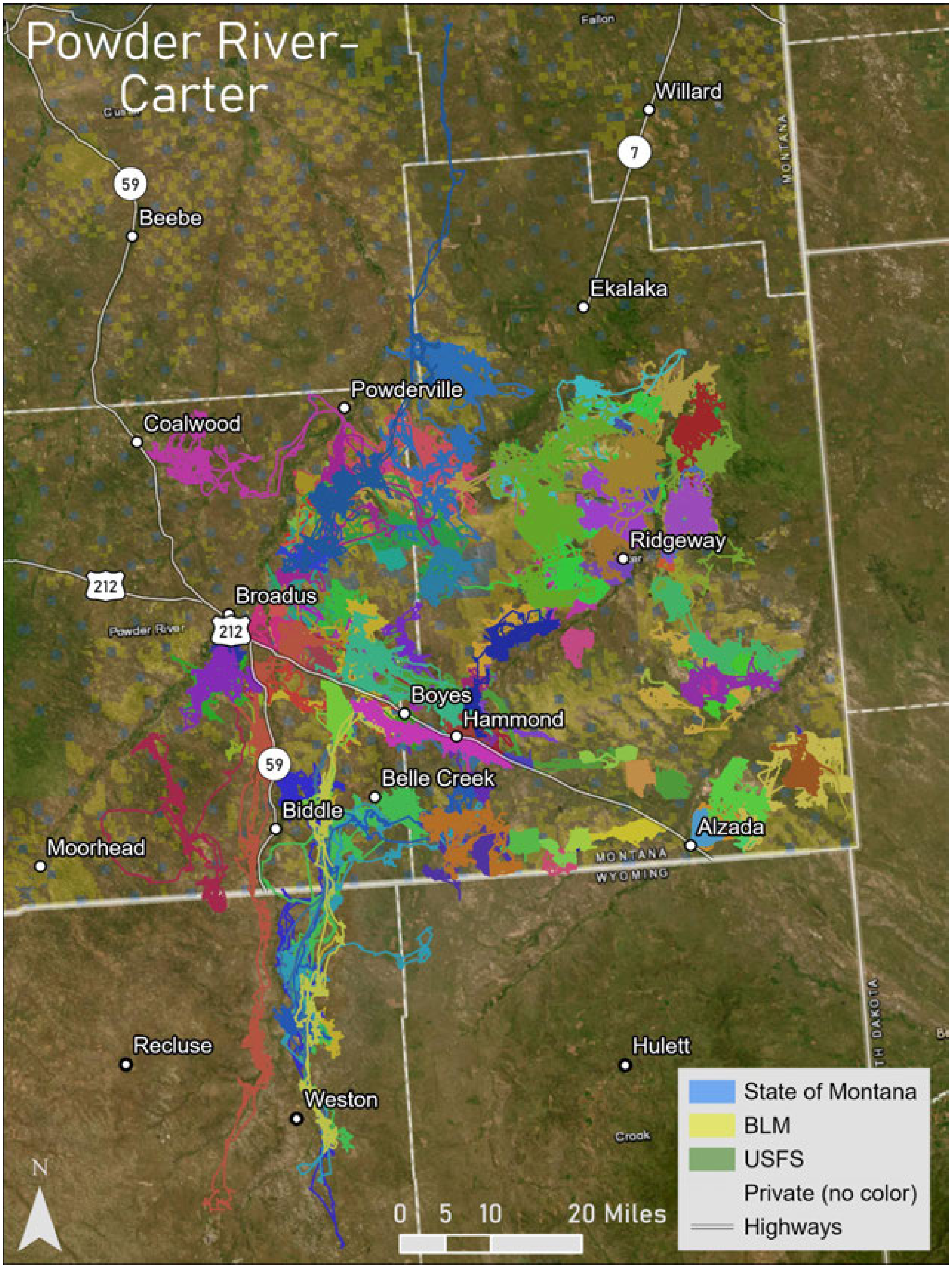


Figure 30. Movements of collared adult female pronghorn (colored by individual) in the Powder River-Carter study area for the Montana Pronghorn Movement and Population Ecology Project from January 2020 to June 2023.

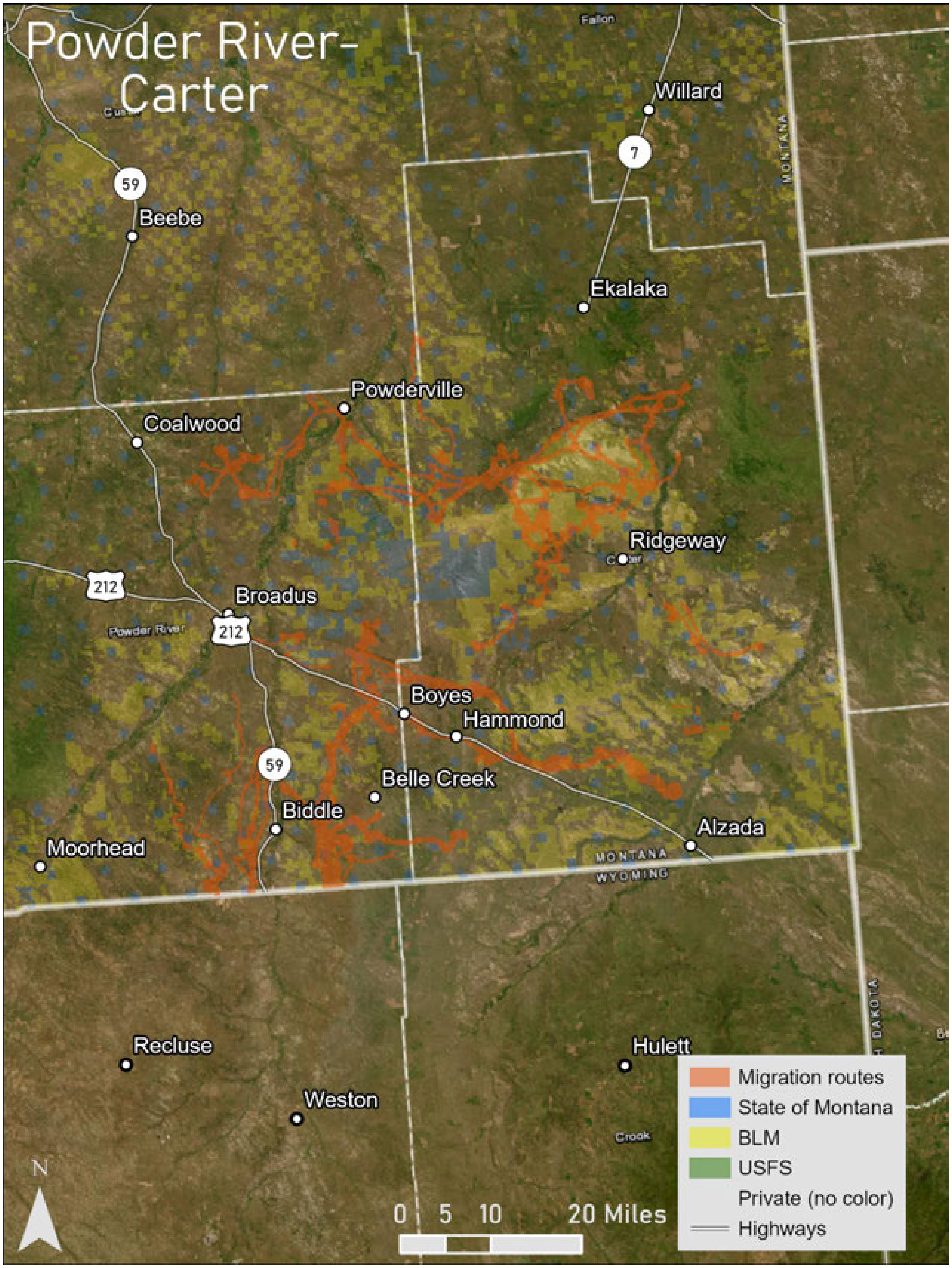


Figure 31. Estimated migration routes of migrant collared adult female pronghorn in the Powder River-Carter study area for the Montana Pronghorn Movement and Population Ecology Project. Migration routes represent areas used by ≥1 migrant during spring and/or fall migration periods from January 2020 to June 2023 and are clipped to Montana only.

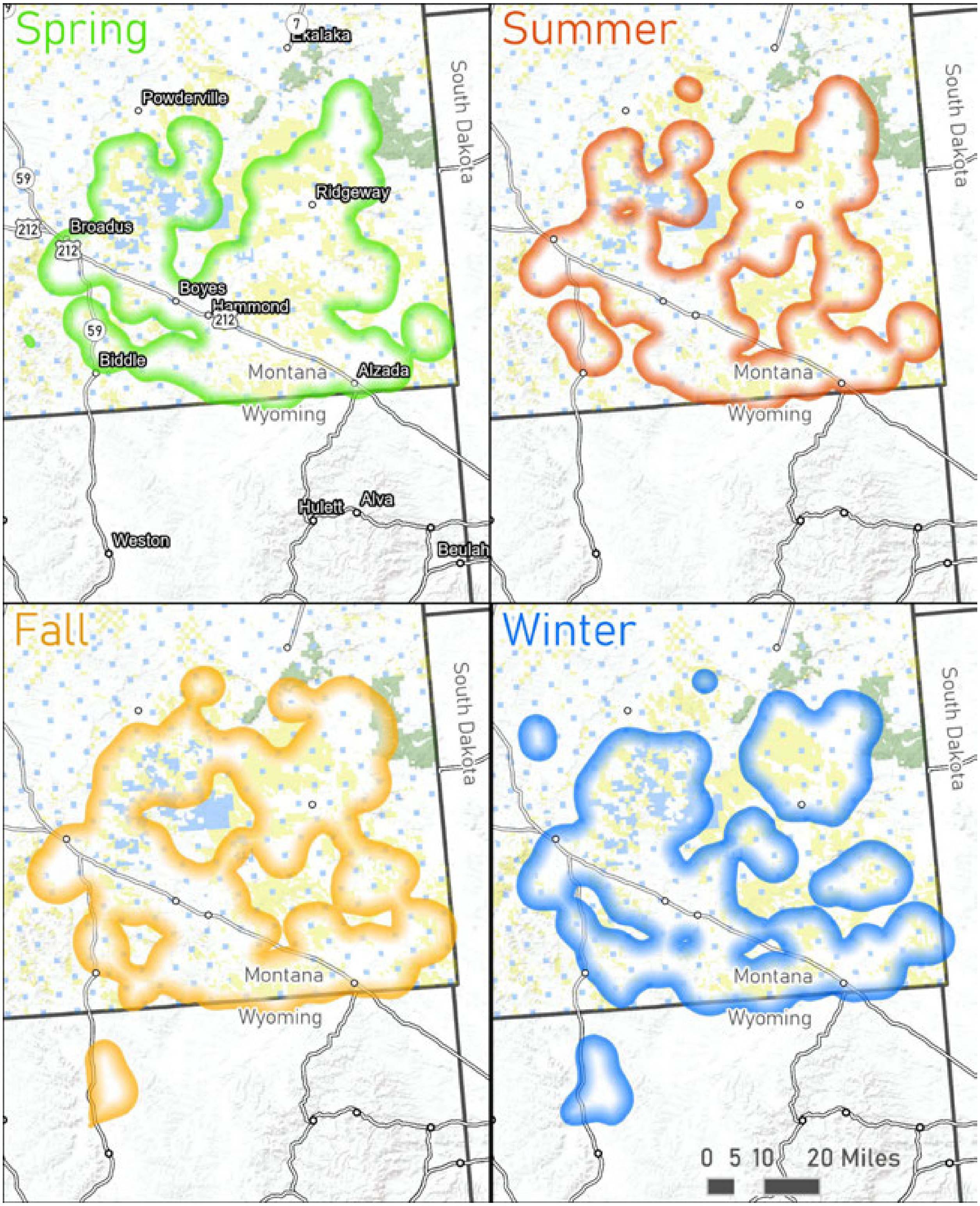


Figure 32. Seasonal ranges of collared adult female pronghorn in the Powder River-Carter area for the Montana Pronghorn Movement and Population Ecology Project from January 2020 to June 2023. Spring: Apr 1 – Jun 30; Summer: Jul 1 – Aug 31; Fall: Sep 1 – Nov 30; Winter: Dec 1 – Mar 31.

1.2 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 (see *Section 1.1 Seasonal ranges and migration routes*; 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 33 – 34).

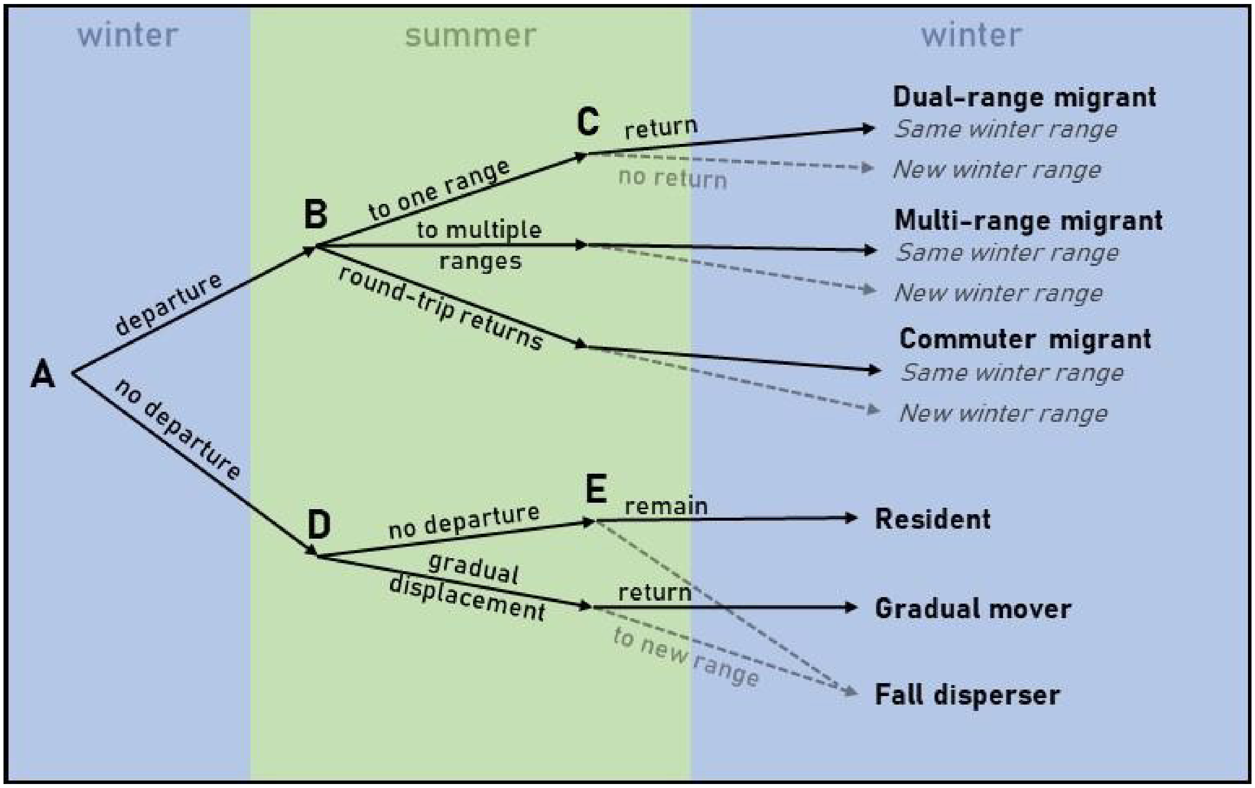


Figure 33. Decision tree adapted from van de Kerk et al. (2021) indicating how we categorized migration strategies from movement trajectories of each animal's migratory year (Feb 01 – Jan 31) for pronghorn captured between 2019 and 2023 in Montana, USA.

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 (Figure 34). 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 (unless only a fall migration existed), 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.

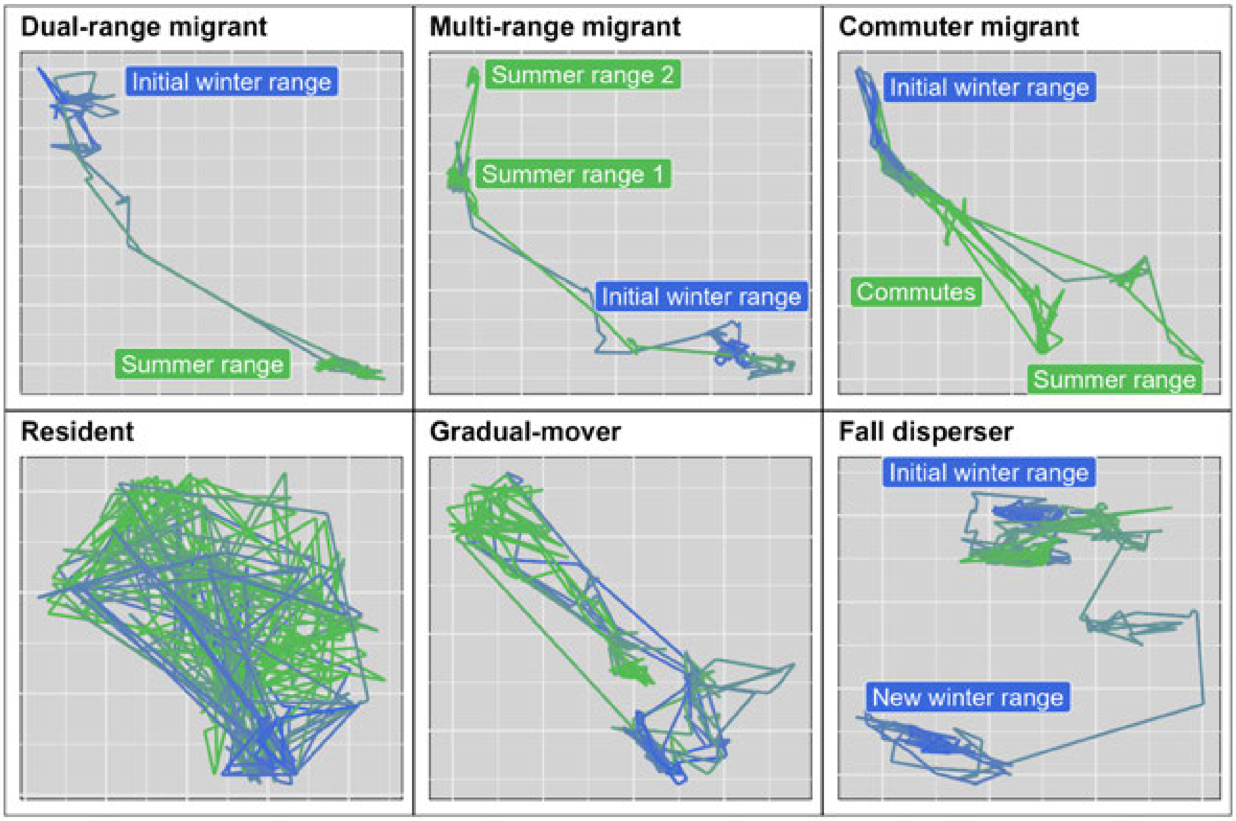


Figure 34. Examples of movement trajectories for a migratory year (Feb 01 – Jan 31) classified into 6 migration strategies based on our decision tree (Figure 33). Green colors represent summer movements and blue colors represent winter movements.

Of the 702 collared pronghorn, a total of 516 individuals and 1,011 animal-years (29, 300, 359, and 323 animal-years for 2019, 2020, 2021, and 2022, respectively) had sufficient data (i.e., >336 days or within 1 month of the end of the migratory year on January 31) to characterize migratory strategies. Of these individuals, 198 (38%), 152 (30%), 155 (30%), and 11 (2%) had 1, 2, 3, and 4 years of data, respectively. The number of animal-years per study area averaged 126 and ranged from 60 in Paradise to 153 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 04 Apr (range = 06 Feb – 18 Jul) and

13 Apr (range = 09 Feb – 29 Jul) for spring and 16 Oct (range = 19 Jun – 18 Dec) and 23 Oct (range = 21 Jun – 25 Dec) for fall (Figure 35). Departure and arrival dates of migratory individuals for spring and fall varied by year (Figure 36) and study area (Table 7, Figure 37 – 41). Migration distances averaged 46 km (median = 36, SD = 33.7, range = 10 – 195) across study areas and varied by study area (Figure 45).

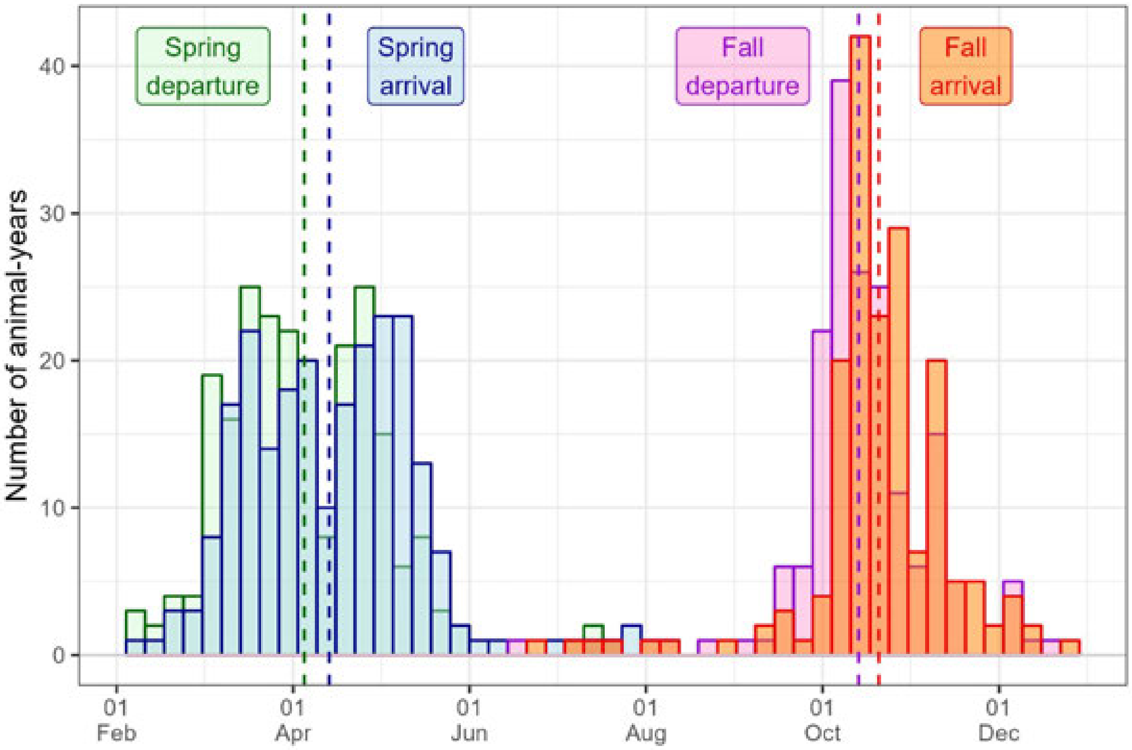


Figure 35. Distribution and average (vertical dashed lines) of migratory departure (spring $\bar{x} = 04$ Apr and fall $\bar{x} = 16$ Oct) and arrival (spring $\bar{x} = 13$ Apr and fall $\bar{x} = 23$ Oct) dates across all years (2019 – 2022) and study areas of migratory collared pronghorn in Montana, USA.

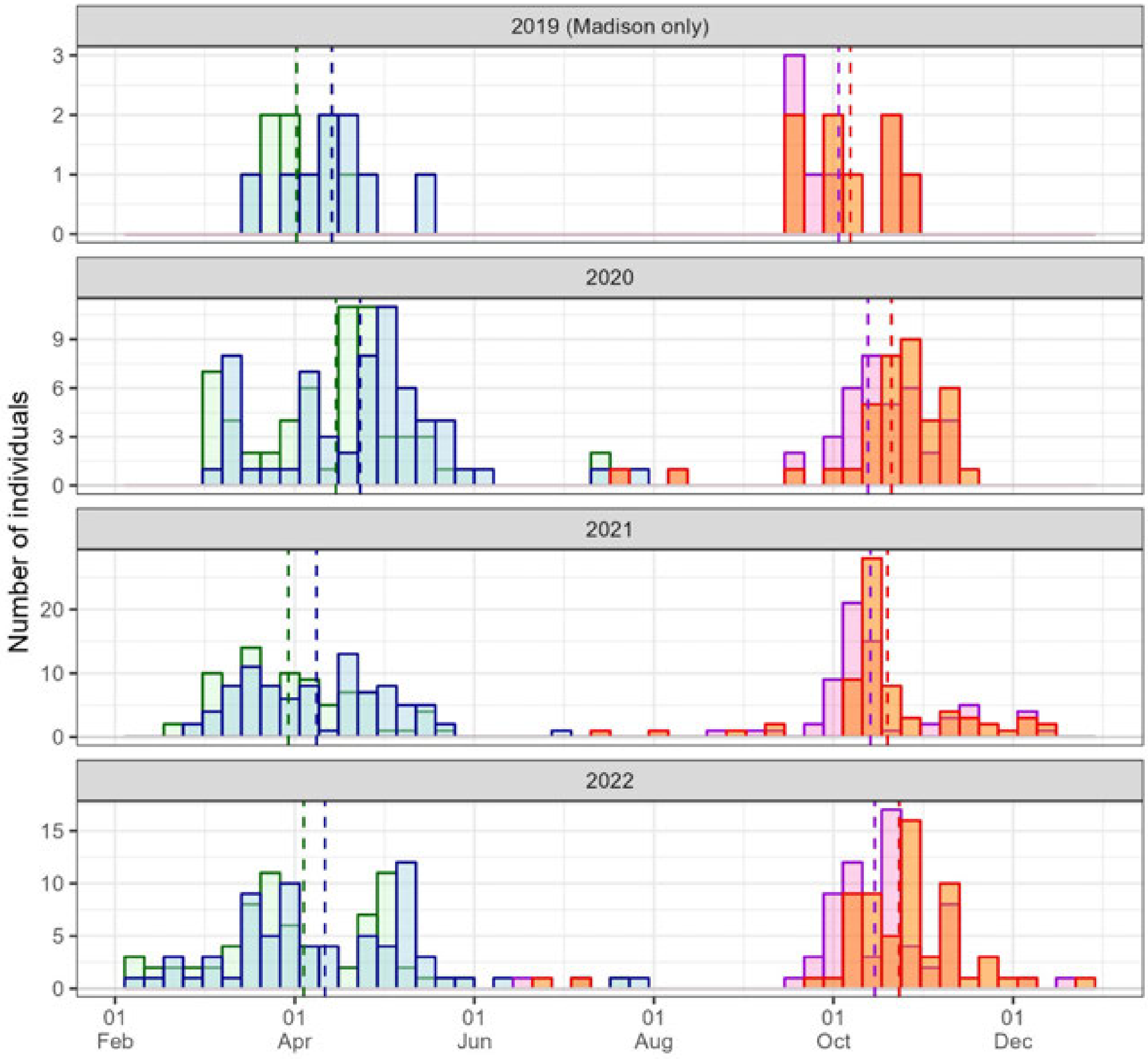


Figure 36. Distribution and average (vertical dashed lines) of dates of spring departure (green), spring arrival (blue), fall departure (purple), and fall arrival (orange) for each year across all study areas of migratory pronghorn captured between 2019 and 2023 in Montana, USA. Note differences in y-axis scales.

Table 7. Average and range of migratory departure and arrival dates for spring and fall migrations for each study area of pronghorn captured between 2019 and 2023 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)

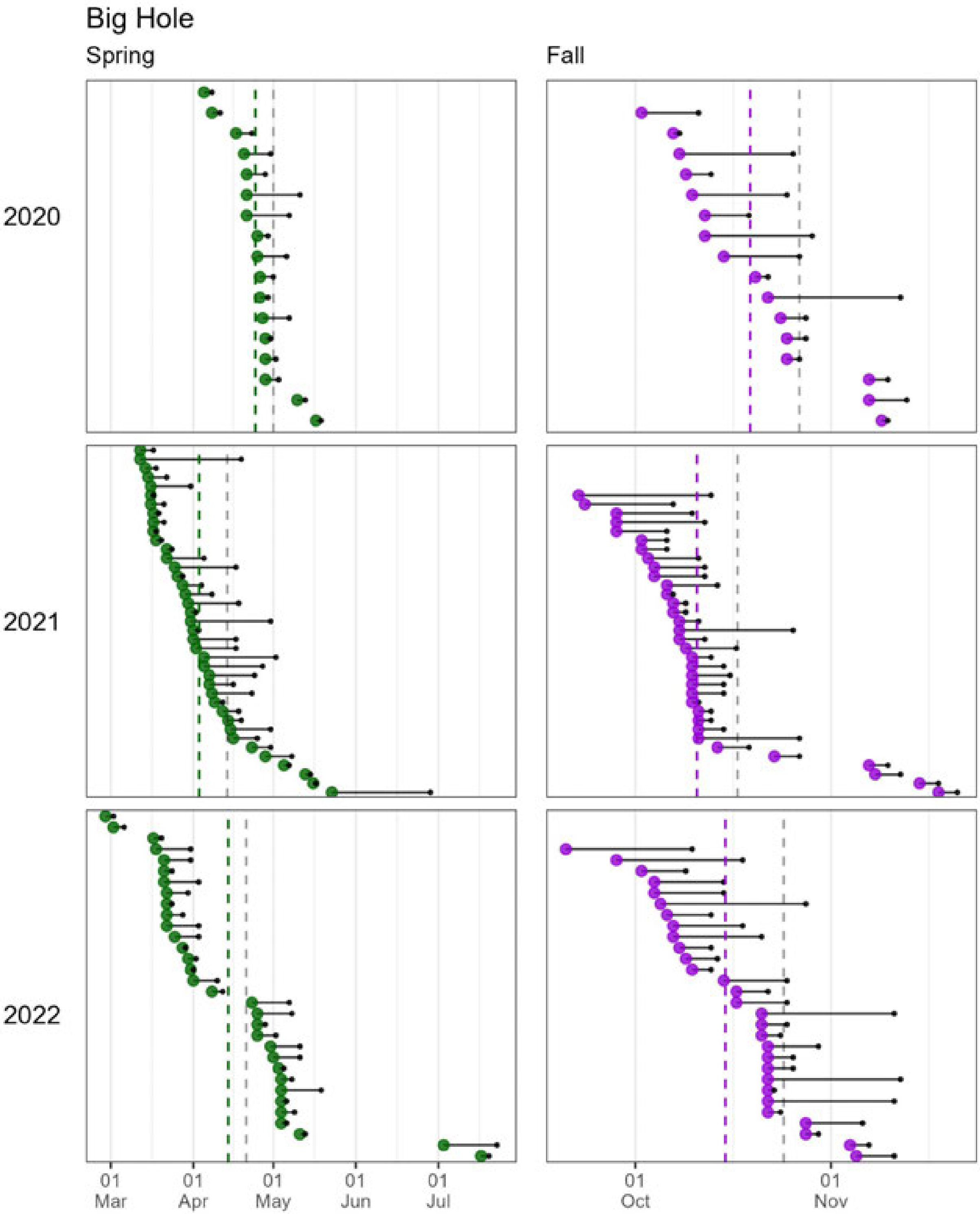


Figure 37. Timing of spring and fall migrations for individuals (y-axis) in the Big Hole study area for 2020 – 2022. Points and horizontal bars represent individual pronghorn departure (green/purple) and arrival (black) dates. Dashed vertical bars represent the average departure and arrival date for each season and year. Note different x-axis scales between spring and fall panels.

Figure 38. Timing of spring and fall migrations for individuals (y-axis) in the Madison study area for 2020 – 2022. Points and horizontal bars represent individual pronghorn departure (green/purple) and arrival (black) dates. Dashed vertical bars represent the average departure and arrival date for each season and year. Note different x-axis scales between spring and fall panels.

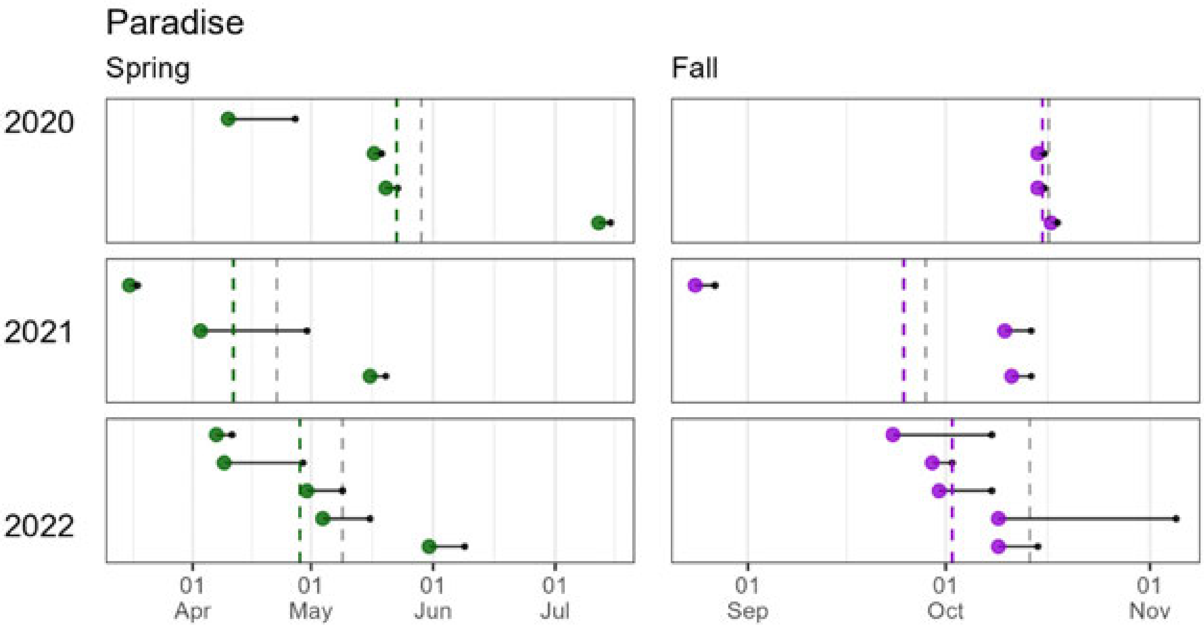


Figure 39. Timing of spring and fall migrations for individuals (y-axis) in the Paradise study area for 2020 – 2022. Points and horizontal bars represent individual pronghorn departure (green/purple) and arrival (black) dates. Dashed vertical bars represent the average departure and arrival date for each season and year. Note different x-axis scales between spring and fall panels.

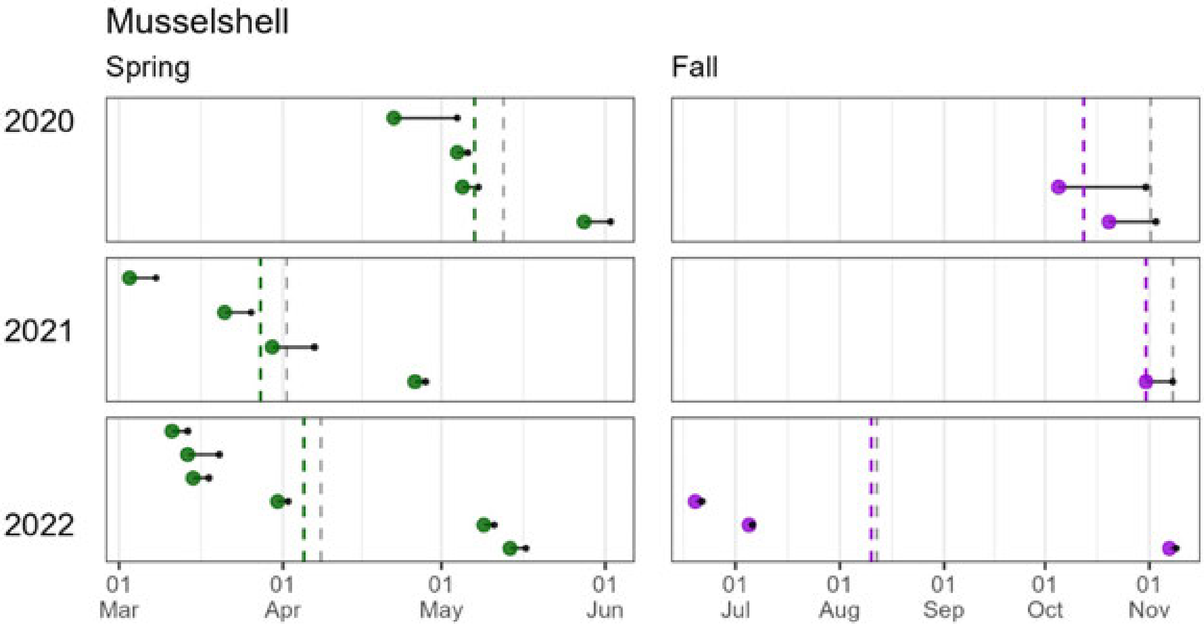


Figure 40. Timing of spring and fall migrations for individuals (y-axis) in the Musselshell study area for 2020 – 2022. Points and horizontal bars represent individual pronghorn departure (green/purple) and arrival (black) dates. Dashed vertical bars represent the average departure and arrival date for each season and year. Note different x-axis scales between spring and fall panels.

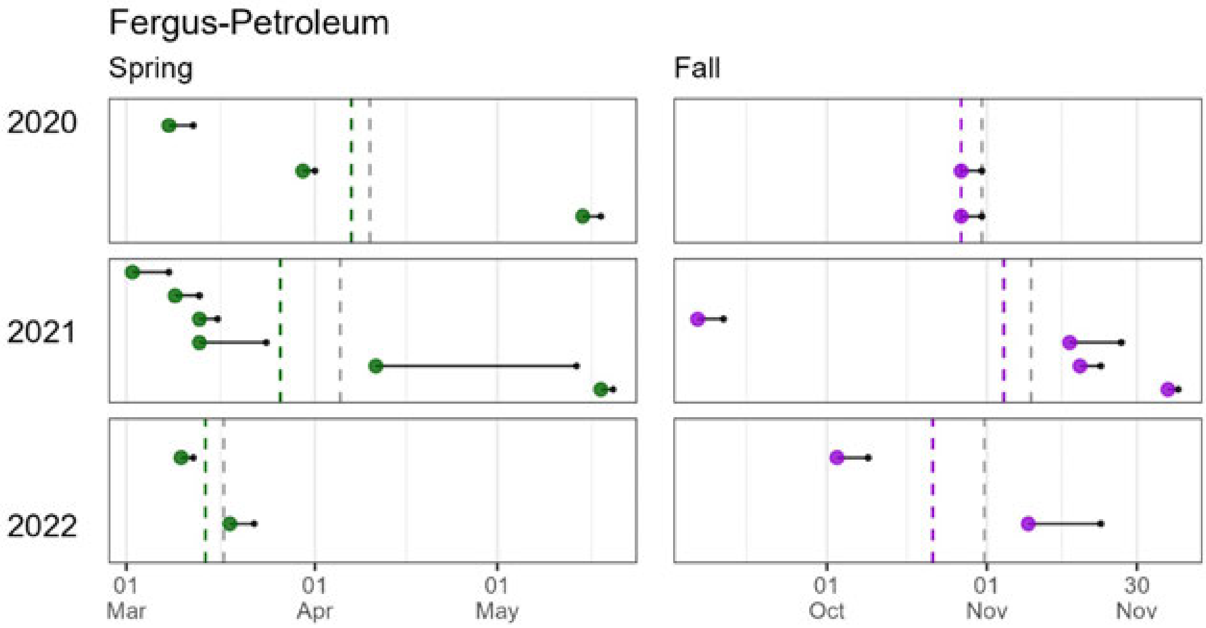


Figure 41. Timing of spring and fall migrations for individuals (y-axis) in the Fergus-Petroleum study area for 2020 – 2022. Points and horizontal bars represent individual pronghorn departure (green/purple) and arrival (black) dates. Dashed vertical bars represent the average departure and arrival date for each season and year. Note different x-axis scales between spring and fall panels.

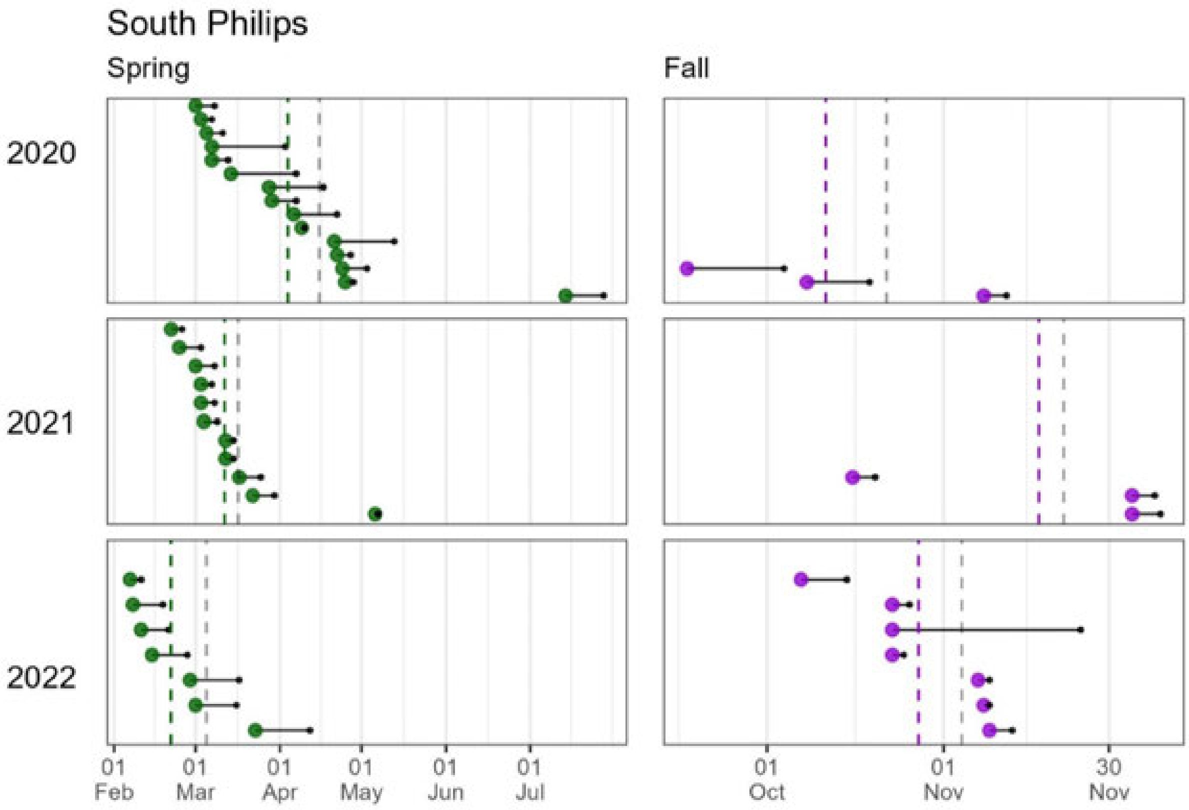


Figure 42. Timing of spring and fall migrations for individuals (y-axis) in the South Philips study area for 2020 – 2022. Points and horizontal bars represent individual pronghorn departure (green/purple) and arrival (black) dates. Dashed vertical bars represent the average departure and arrival date for each season and year. Note different x-axis scales between spring and fall panels.

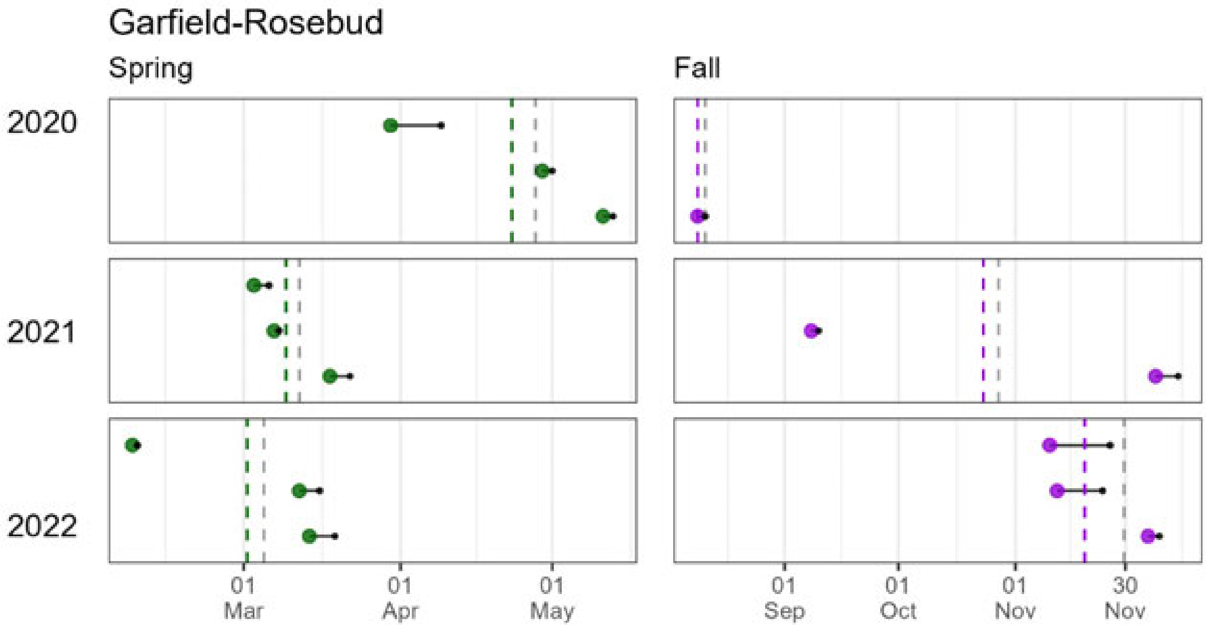


Figure 43. Timing of spring and fall migrations for individuals (y-axis) in the Garfield-Rosebud study area for 2020 – 2022. Points and horizontal bars represent individual pronghorn departure (green/purple) and arrival (black) dates. Dashed vertical bars represent the average departure and arrival date for each season and year. Note different x-axis scales between spring and fall panels.

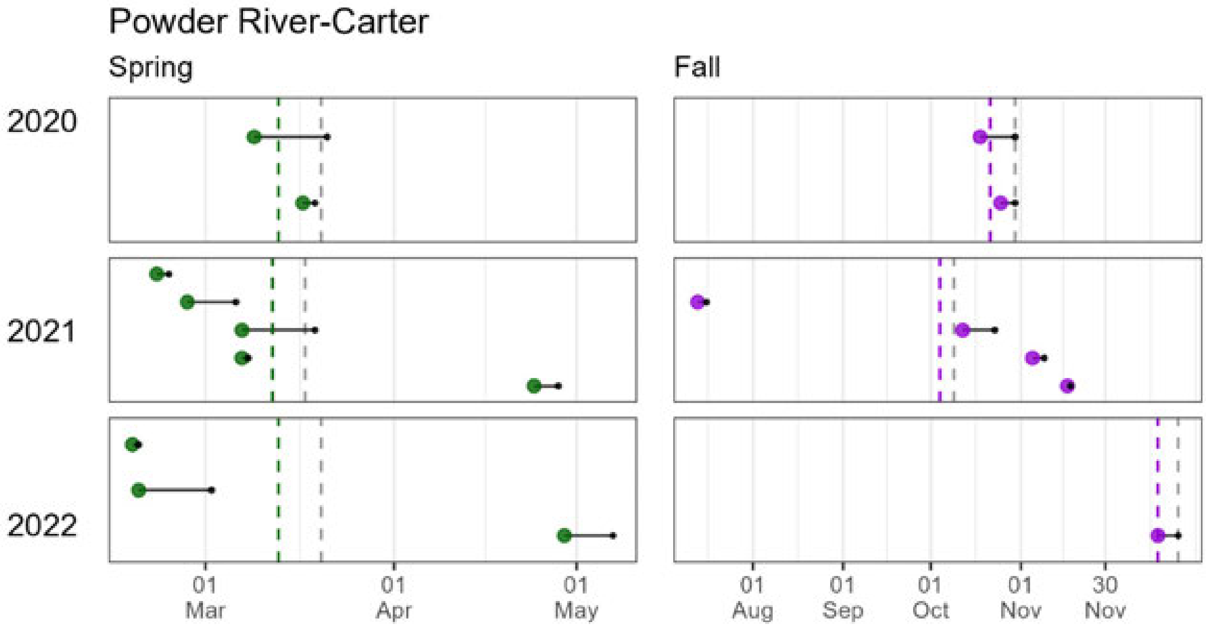


Figure 44. Timing of spring and fall migrations for individuals (y-axis) in the Powder River-Carter study area for 2020 – 2022. Points and horizontal bars represent individual pronghorn departure (green/purple) and arrival (black) dates. Dashed vertical bars represent the average departure and arrival date for each season and year. Note different x-axis scales between spring and fall panels.

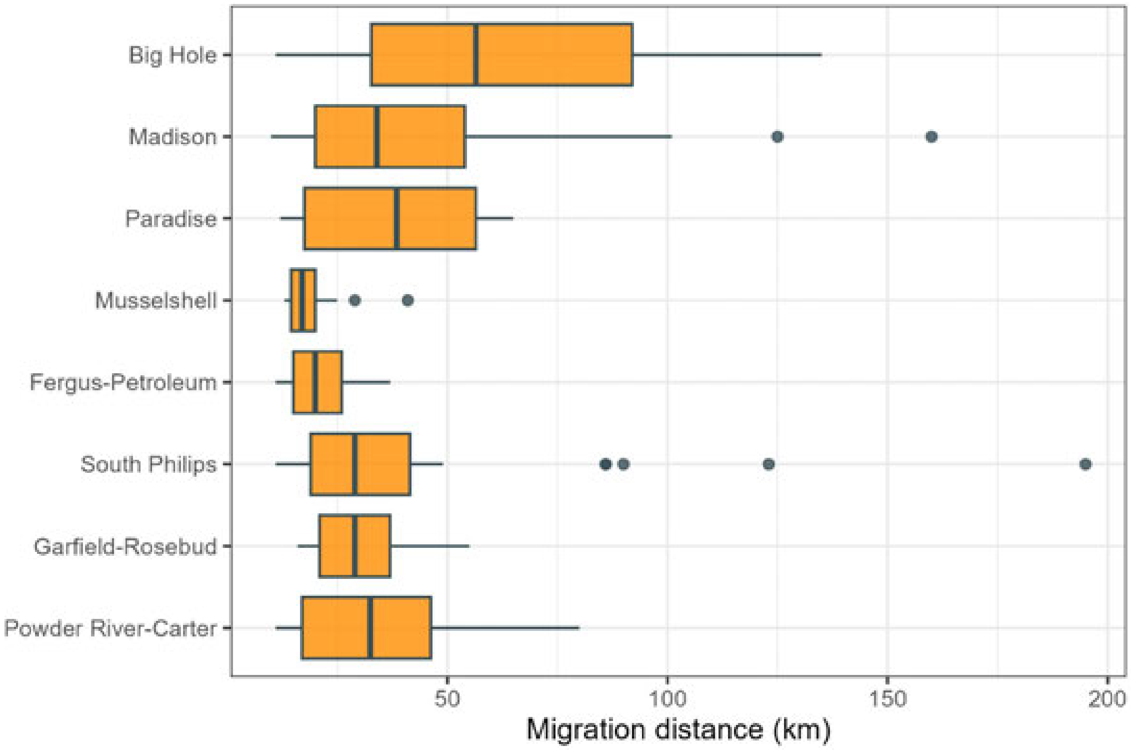


Figure 45. Distributions of migratory distances of migratory individuals in each study area of pronghorn during 2020 – 2023 (2019 – 2023 in Madison) in Montana, USA. Distances were measured following the animal's spring migratory pathway to its furthest summer range. Vertical lines through boxes represent 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, most animal-years (n = 782, 77.3%) did not distinctly depart their initial winter range during the summer, with over half of all animal-years (n = 593, 58.7% of total) remaining as residents, 114 (11.3% of total) exhibiting gradual range shifts as gradual movers, and 75 (7.4% of total) departing to new winter ranges during the fall (i.e., fall dispersers; Figure 46). The percent of animal-years classified as either resident, gradual mover, or fall disperser each year ranged from 25.0% in Big Hole to 95.8% in Fergus-Petroleum (Table 8).

The remainder of animal-years, comprising nearly a fourth of all animal-years (n = 229, 22.7%), distinctly departed their initial winter range and moved to summer range, with 186 (18.4% of total) classified as dual-range migrants, 37 (3.6% of total) classified as multi-range migrants, and 6 (0.6% of total) classified as commuter migrants. Of these, 148 (64.6% of those departed) animal-years returned to their initial winter range and 81 (35.4% of those departed) dispersed to a new winter range. Proportions of migratory classifications varied by study area and year (Figure 47 – 49; Table 8).

Across all migratory strategies, the percent of animal-years returning to their initial winter range each year averaged 85.2% and ranged from 57.8% in South Philips to 100% in Paradise and Fergus-Petroleum. Of the animal-years that had enough data to determine summer range fidelity in subsequent years (n = 496), the percent of animal-years returning to their initial summer range each year averaged 98.1% and ranged from 89.7% in Big Hole to 100% in Big Hole, Madison, Paradise, Musselshell, Fergus-Petroleum, Garfield-Rosebud, and Powder River-Carter.

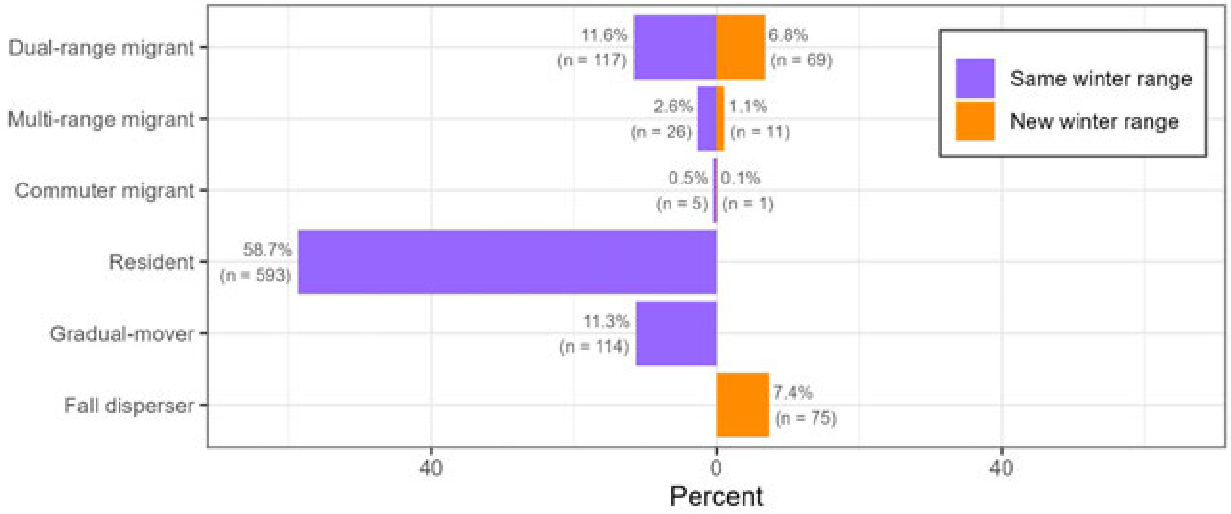


Figure 46. Percent of animals classified into migratory strategy classes and whether they returned to their original (purple) or a new (orange) winter range summarized across years and study areas of pronghorn during 2020 – 2023 (2019 – 2023 in Madison) in Montana, USA.

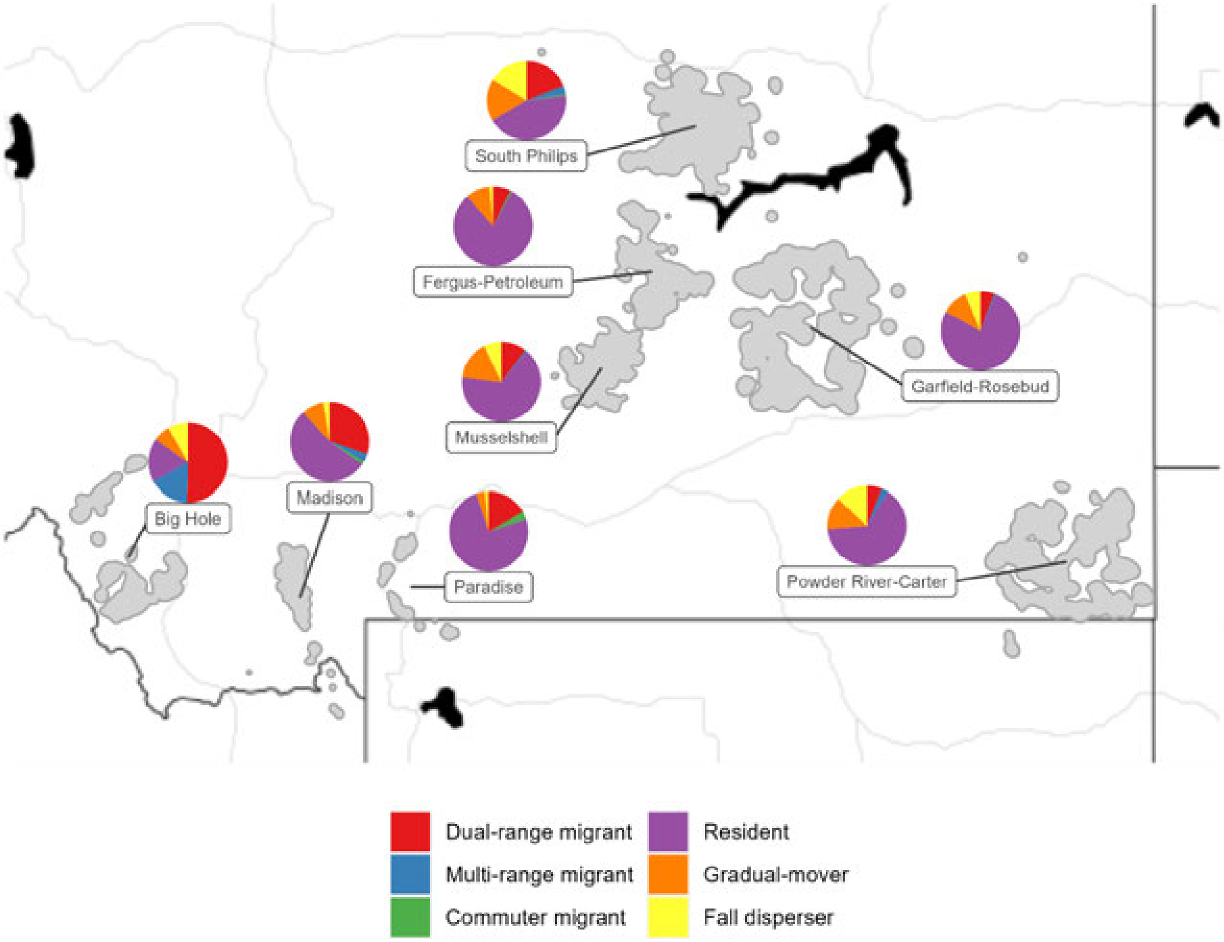


Figure 47. Map of the proportion of migratory behaviors in each study area across all study years (2020-2022; the Madison also includes 2019).

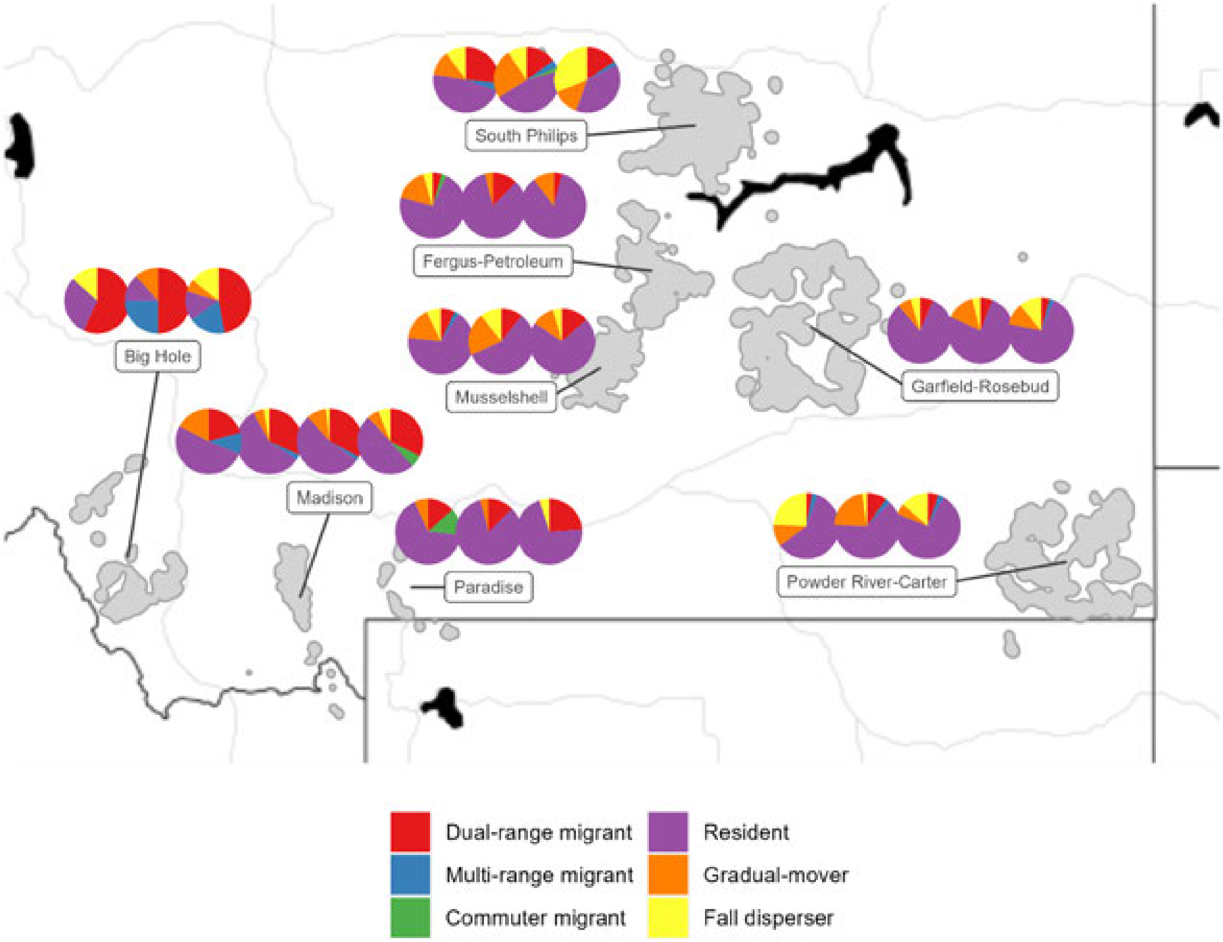


Figure 48. Map of the proportion of migratory behaviors in each consecutive study year (2020-2022) and study area (the Madison includes an extra chart for 2019).

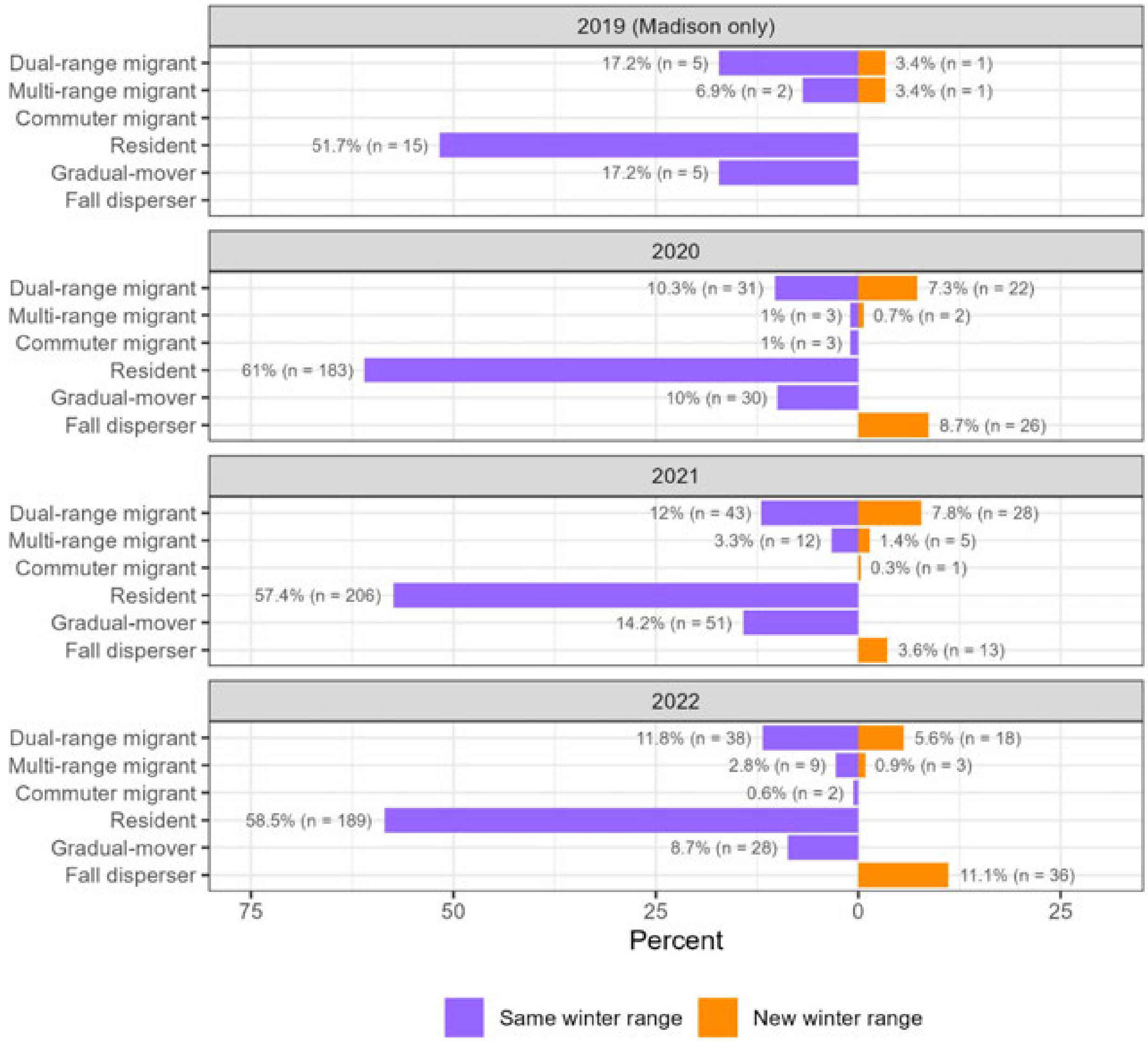


Figure 49. Proportion of animals classified into migratory strategy classes and whether they returned to their original (purple) or a new (orange) winter range for each year across pronghorn study areas in Montana, USA.

Table 8. Number and proportion of animals classified into each migratory class for each year and pronghorn study area in Montana, USA.

Study area	Migration behavior	2019	2020	2021	2022
Big Hole	Dual-range migrant	--	17 (0.57)	26 (0.50)	21 (0.45)
	Multi-range migrant	--	--	13 (0.25)	9 (0.19)
	Resident	--	9 (0.30)	7 (0.13)	7 (0.15)
	Gradual-mover	--	--	6 (0.12)	3 (0.06)
	Fall disperser	--	4 (0.13)	--	7 (0.15)
	Total	--	30	52	47
Madison	Dual-range migrant	6 (0.21)	12 (0.32)	17 (0.33)	11 (0.32)
	Multi-range migrant	3 (0.10)	1 (0.03)	1 (0.02)	--
	Commuter migrant	--	--	--	2 (0.06)
	Resident	15 (0.52)	22 (0.58)	28 (0.54)	17 (0.50)
	Gradual-mover	5 (0.17)	2 (0.05)	5 (0.10)	2 (0.06)
	Fall disperser	--	1 (0.03)	1 (0.02)	2 (0.06)
	Total	29	38	52	34
Paradise	Dual-range migrant	--	2 (0.13)	3 (0.12)	5 (0.24)
	Commuter migrant	--	2 (0.13)	--	--
	Resident	--	10 (0.67)	20 (0.83)	15 (0.71)
	Gradual-mover	--	1 (0.07)	1 (0.04)	--
	Fall disperser	--	--	--	1 (0.05)
	Total	--	15	24	21
Musselshell	Dual-range migrant	--	3 (0.07)	4 (0.11)	6 (0.13)
	Multi-range migrant	--	1 (0.02)	--	--
	Resident	--	29 (0.67)	22 (0.58)	32 (0.71)
	Gradual-mover	--	7 (0.16)	8 (0.21)	5 (0.11)
	Fall disperser	--	3 (0.07)	4 (0.11)	2 (0.04)
	Total	--	43	38	45
Fergus-Petroleum	Dual-range migrant	--	2 (0.05)	6 (0.12)	2 (0.04)
	Commuter migrant	--	1 (0.02)	--	--
	Resident	--	31 (0.72)	41 (0.84)	41 (0.85)
	Gradual-mover	--	7 (0.16)	2 (0.04)	5 (0.10)
	Fall disperser	--	2 (0.05)	--	--
	Total	--	43	49	48
South Philips	Dual-range migrant	--	13 (0.27)	8 (0.15)	7 (0.16)
	Multi-range migrant	--	2 (0.04)	2 (0.04)	1 (0.02)
	Commuter migrant	--	--	1 (0.02)	--
	Resident	--	23 (0.47)	24 (0.45)	17 (0.38)
	Gradual-mover	--	6 (0.12)	13 (0.25)	6 (0.13)
	Fall disperser	--	5 (0.10)	5 (0.09)	14 (0.31)
	Total	--	49	53	45
Garfield-Rosebud	Dual-range migrant	--	3 (0.07)	3 (0.06)	2 (0.04)
	Multi-range migrant	--	--	--	1 (0.02)
	Resident	--	37 (0.84)	38 (0.76)	33 (0.72)
	Gradual-mover	--	2 (0.05)	7 (0.14)	5 (0.11)
	Fall disperser	--	2 (0.05)	2 (0.04)	5 (0.11)
	Total	--	44	50	46
Powder River-Carter	Dual-range migrant	--	1 (0.03)	4 (0.10)	2 (0.05)
	Multi-range migrant	--	1 (0.03)	1 (0.02)	1 (0.03)
	Resident	--	22 (0.59)	26 (0.63)	27 (0.73)
	Gradual-mover	--	4 (0.11)	9 (0.22)	2 (0.05)
	Fall disperser	--	9 (0.24)	1 (0.02)	5 (0.14)
	Total	--	37	41	37

We observed 160 instances of individuals switching migratory strategies from one year to the next (Figures 50 - 52). From a total of 22 individuals classified into a migratory strategy 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. Of these, 15 individuals were also classified for 2021 from which 4 (26.7%) switched, including 1 from dual-range migrant to fall disperser, 1 multi-range migrant to dual-range migrant, and 2 residents to gradual-movers.

From a total of 229 individuals classified for 2020 and 2021, 78 (34.1%) animals switched. The majority of these animals switched from resident to gradual-mover (n = 16, 20.5%), gradual-mover to resident (n = 17, 21.8%), and fall disperser to dual-range migrant (n = 11, 14.1%). The remainder included 13 (16.9%) switches between migrant and non-departure classes (5 dual-range migrant to gradual-movers, 4 dual-range migrant to resident, 2 dual-range migrant to fall disperser, 1 multi-range migrant to resident, and 1 gradual-mover to multi-range migrant), 12 (15.4%) switches between non-migrant classes (5 resident to fall disperser, 3 fall disperser to gradual-mover, 3 fall disperser to resident, and 1 gradual-mover to fall disperser), and 9 (11.7%) switches between migrant classes (4 dual-range to multi-range, 1 dual-range to commuter, 2 multi-range to dual-range, 2 commuter to dual-range).

From a total of 244 individuals classified for 2021 and 2022, 77 (31.6%) animals switched. The majority of these switched from gradual-mover to resident (n = 13, 16.9%), gradual-mover to fall disperser (n = 12, 15.6%), resident to fall disperser (n = 8, 10.4%), and dual-range migrant to fall disperser (n = 8, 10.4%). The remainder included 18 (23.4%) switches between migrant and non-migrant departure classes (7 dual-range to resident, 2 dual-range to gradual-mover, 1 commuter to fall disperser, 3 fall disperser to dual-range migrant, 2 fall disperser to multi-range migrant, and 3 resident to dual-range migrant), 11 (14.3%) switches between migrant classes (2 dual-range to multi-range, 2 dual-range to commuter, and 7 multi-range to dual-range), and 7 (9.1%) switches between non-migrant classes (6 resident to gradual-mover, 1 fall disperser to resident).

Of the 78 individuals that switched migratory strategies between 2020 and 2021, 31 (39.7%) switched again in 2022. The majority of these animals switched from resident to gradual-mover to resident (n = 6, 19.4%), resident to dual-range migrant to fall disperser (n = 4, 12.9%), and fall disperser to dual-range migrant to fall disperser (n = 5, 16.1%), dual-range migrant to multi-range migrant to dual-range migrant (n = 2, 6.5%), dual-range migrant to commuter migrant to fall disperser (n = 2, 6.5%), dual-range to gradual-mover to fall disperser (n = 2, 6.5%), dual-range migrant to gradual-mover to resident (n = 2, 6.5%), and dual-range migrant to fall disperser to dual-range migrant (n = 2, 6.5%).

A total of 11 individuals had 4 years (2019 – 2022) of migratory data (i.e., Madison animals only), of which 5 demonstrated migratory switching strategy at some point during the study. Two individuals were residents for 2019 and 2020, switched to gradual-mover in 2021, and returned to residents in 2022. One individual switched every year, from gradual-mover to dual-range migrant to fall disperser to dual-range migrant. One individual switched from a dual-range migrant in 2019 to a resident in both 2020 and 2021 and then switched to a fall disperser in 2022. One individual remained a dual-range migrant for the first 3 years before switching to a commuter migrant in 2022.

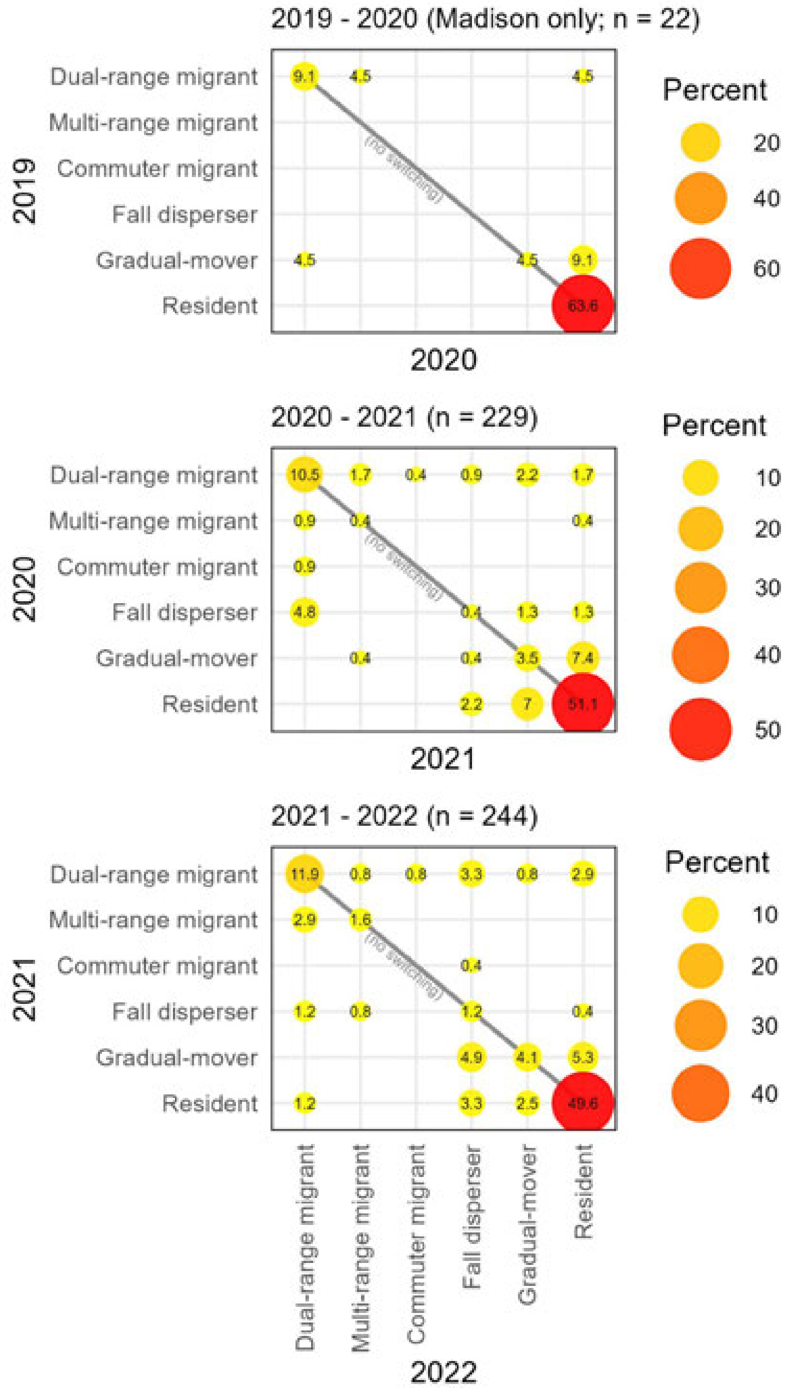


Figure 50. Percent of migratory strategy classification switches between pairs of years from 2019 – 2022 in Montana, USA. The migratory strategies occurring in the first year are displayed on the y-axis and in the second year on the x-axis. Values occurring along the diagonal line represent proportions of individuals that did not switch between the years (i.e., the "no switching" line). Sample sizes (n) represent total number of individuals (i.e., including both switching and non-switching individuals).

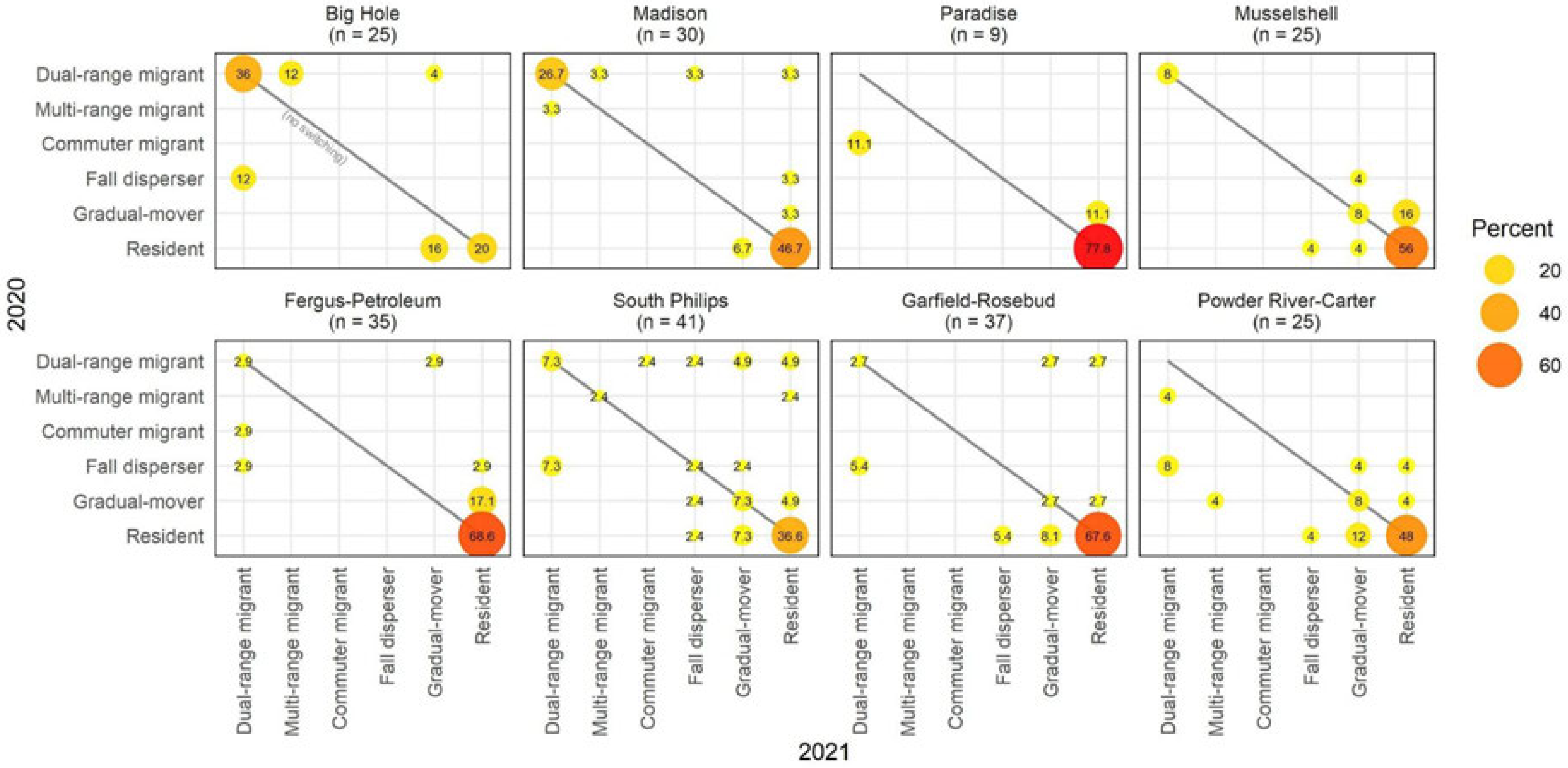


Figure 51. Percent of migratory strategy classification switches between years 2020 (y-axis) and 2021 (x-axis) in each study area of pronghorn captured between 2019 and 2023 in Montana, USA. Values occurring along the diagonal line represent proportions of individuals that did not switch between the years. Sample sizes (n) represent total number of individuals in each study area (i.e., including both switching and non-switching individuals) with sufficient data to classify.

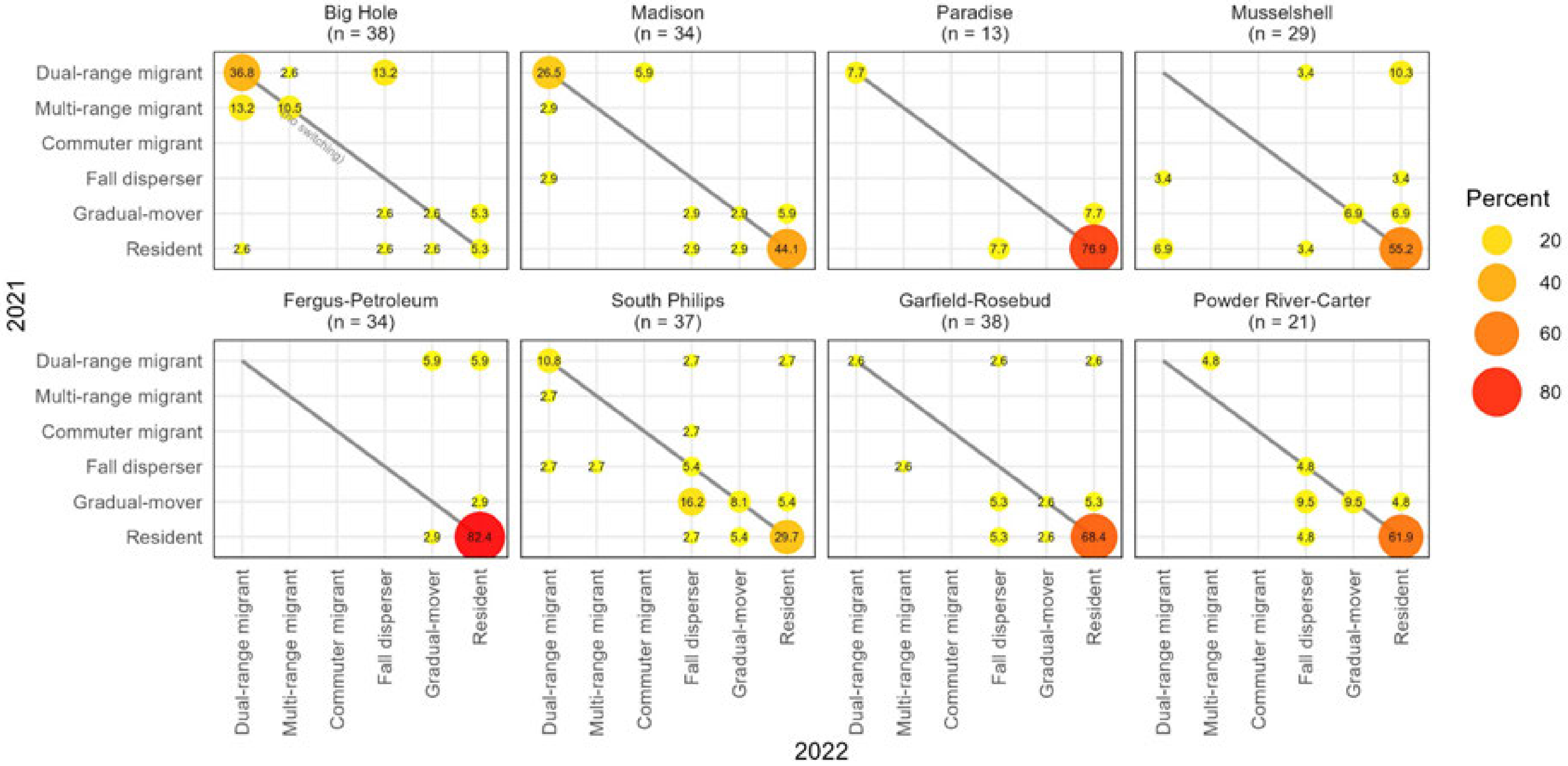


Figure 52. Percent of migratory strategy classification switches between years 2021 (y-axis) and 2022 (x-axis) in each study area of pronghorn captured between 2020 (2019 in Madison) and 2023 in Montana, USA. Values occurring along the diagonal line represent proportions of individuals that did not switch between the years. Sample sizes (n) represent total number of individuals in each study area (i.e., including both switching and non-switching individuals) with sufficient data to classify.

1.3 Survival estimates of resident and migrant pronghorn

To understand if survival varied for migratory strategies, we estimated annual survival rates for resident (i.e., resident, gradual-mover, and fall disperser migratory behaviors) and migratory (i.e., dual-range, multi-range, and commuter migrants) pronghorn based on the migratory year which we defined as April 1 – March 31. Most animals initiated spring migration after April 1 and arrived back on their winter ranges by March 31. We used 784 animal-years of survival data collected during 2019, 2020, and 2021. The mean number of days an individual was monitored was 527 days. We estimated the annual Kaplan-Meier survival rate of residents and migrants and compared resident and migrant survival rates using a log rank test.

A total of 161 mortality events occurred. The estimated annual survival rate for residents was 0.80 (95% CI = 0.77, 0.83) and for migrants was 0.77 (95% CI = 0.70, 0.82). Based on the log rank test, there was no evidence for a difference in the survival rates of residents and migrants (p = 0.33, Figure 53).

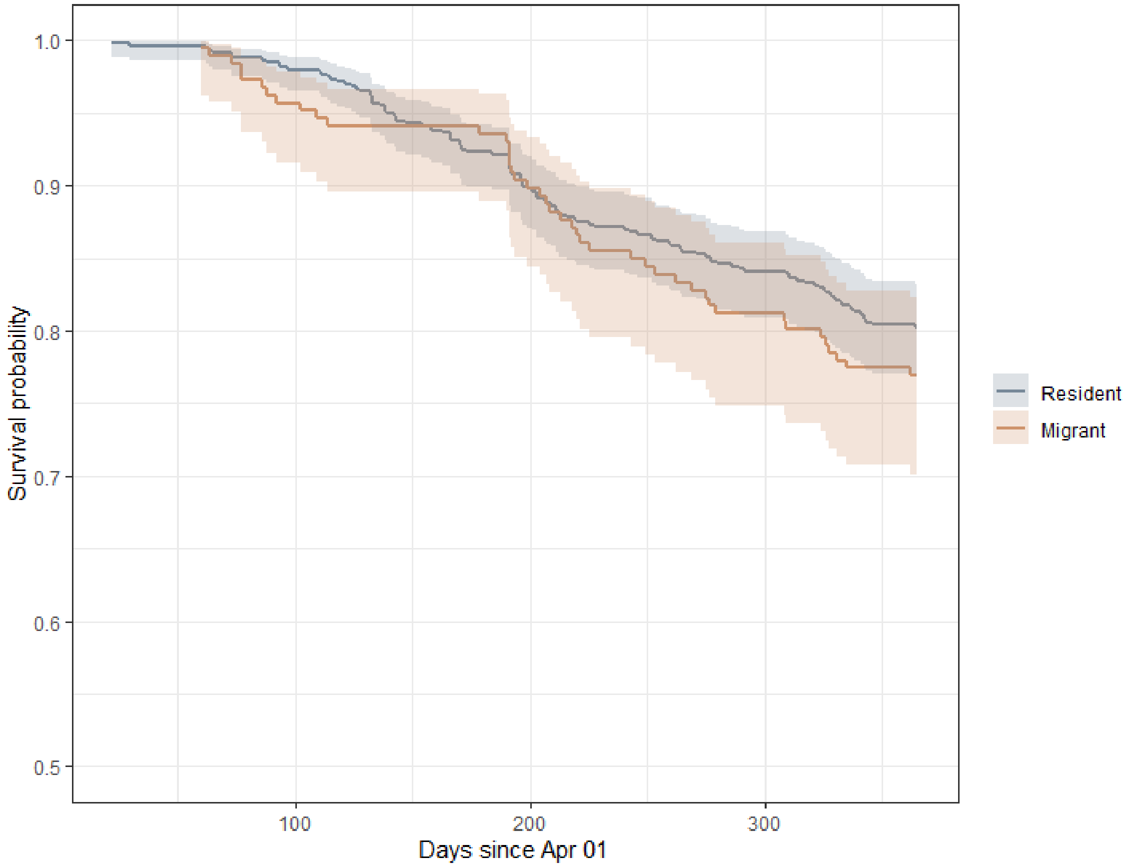
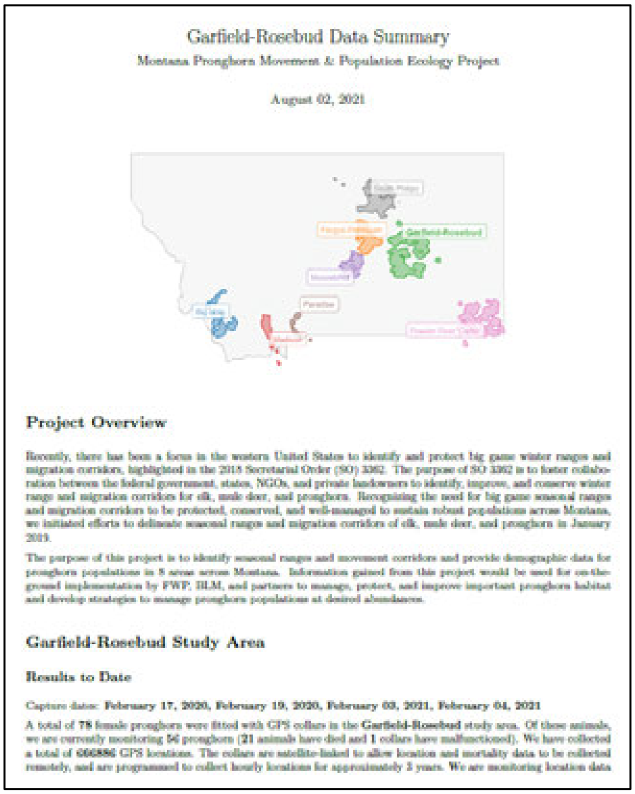


Figure 53. The estimated Kaplan Meier survival curve for resident (blue) and migrant (orange) adult female pronghorn in Montana, USA during 2019-2021.

Objective #2: Create and distribute maps of seasonal range and movement areas for pronghorn

Since the initiation of the collar location data collection, we generated monthly summary reports of animal distributions and movements specific to each study area (Figure 54). These reports included population- and individual-level maps, with individual-level maps showing seasonal movements. On a monthly basis, we distributed these reports to state and federal agency biologists, non-profit conservation organizations, and private landowners. We generated these reports in lieu of a web-based platform but have made location data available to FWP and BLM wildlife staff associated with each study area on an ArcGIS Online platform (see *Section 3.1 Identification of potential barriers to movement*). All animal movement data sharing associated with this project was 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.

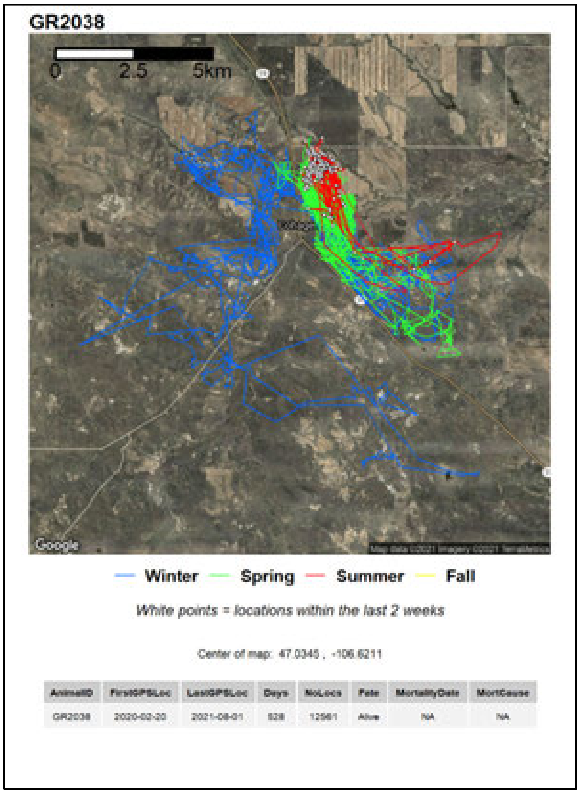
The purpose of this project is to identify seasonal ranges and movement corridors and provide demographic data for pronghorn populations in 8 areas across Montana. Information gained from this project would be used for on-the-ground implementation by FWP, BLM, and partners to manage, protect, and improve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



Winter Spring Summer Fall

White points = locations within the last 2 weeks

Center of map: 47.0345 , -106.6211

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

Figure 54. Example pages from the Garfield-Rosebud monthly summary report generated for distribution to agency biologists and collaborators. Reports were updated and distributed monthly for each of the 8 study areas of the Montana Pronghorn Movement and Population Ecology Project for the duration of the study.

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. At the time this study concluded, some projects were still in progress or scheduled for completion within the next year (see *Section 3.3 Collaborative efforts to remediate movement barriers*). To facilitate the identification of potential barriers to pronghorn movements, we developed 2 tools, including 1) an online platform based in ArcGIS Online for mapping fences and recording fence attributes and 2) interactive maps that display fence permeabilities based on relative frequencies of altered behavioral responses to mapped fences. We discuss each of these products below.

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 55). 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 was 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 provided 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 was added by drawing fences in the office based on aerial maps and in the field using tablets. When in the field, users added attributes to mapped fences, verified and moved positions of mapped fences, and mapped any additional fences. We created an 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 was and will continue to be collected by BLM staff at a broader scale outside the study areas. In addition, fence data has also been contributed to this dataset by the National Wildlife Federation (Buzzard et al. 2022).

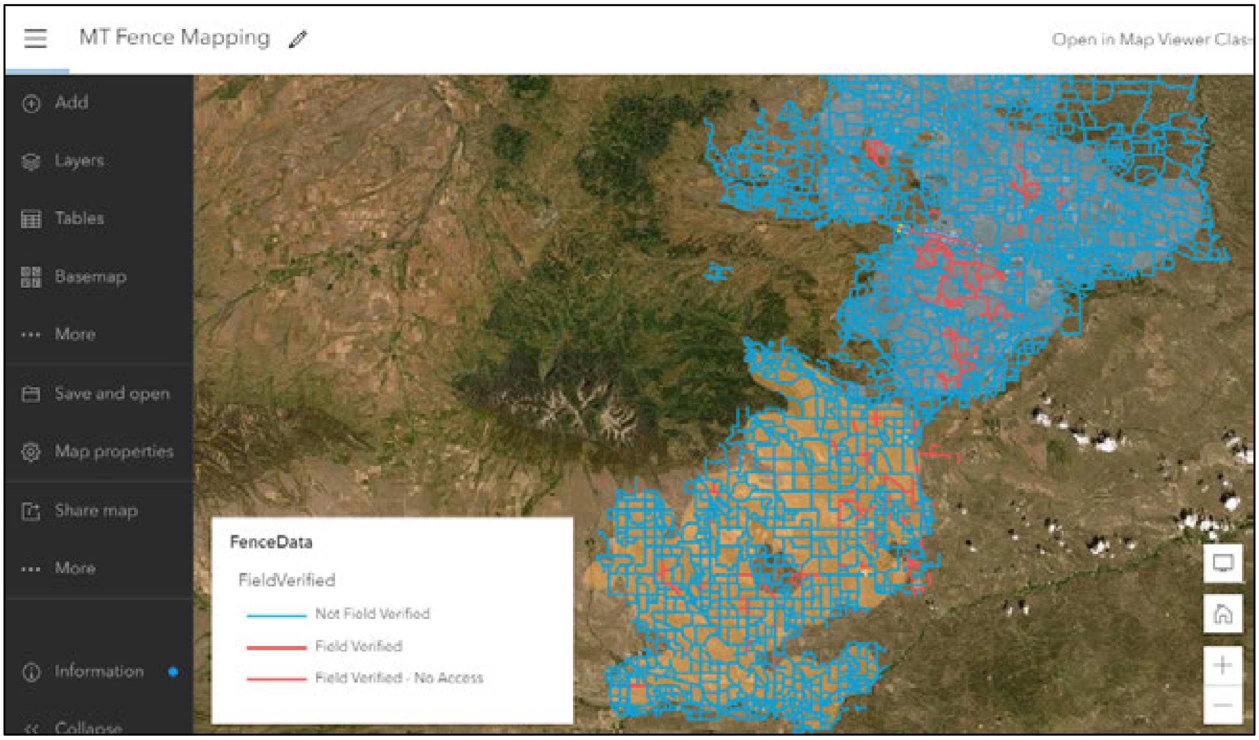


Figure 55. Example of fence spatial data recorded in the field within annual ranges of each population using the online platform on ArcGIS Online as part of the Montana Pronghorn Movement and Population Ecology Project. Red and blue lines represent mapped fences with and without fence characteristics measured in the field, respectively.

Fences were added to the fence data feature layer such that each line was 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 was 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 could then be added to each line feature, or the line feature could be relocated to a more precise location if needed. Our protocol for field visitation included recording the primary and bottom wire type, number of total strands, and bottom and top wire height. The wire height attributes were 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 were then marked as field verified.

We mapped a total of 82,132 fence segments, with 2,244 (5%) verified in the field, equating to approximately 48,694 km and 2,496 km of total and field verified fences, respectively (Figure 56). Of the field verified fences, we classified the majority of the primary wire type as barbed (2,062 km, 82.6%) and woven (404 km, 16.2%). Of those classified as barbed primary wire type, we recorded approximately 2,017 km of barbed bottom strand and 45 km of smooth bottom strand fences (with varying number of strands).

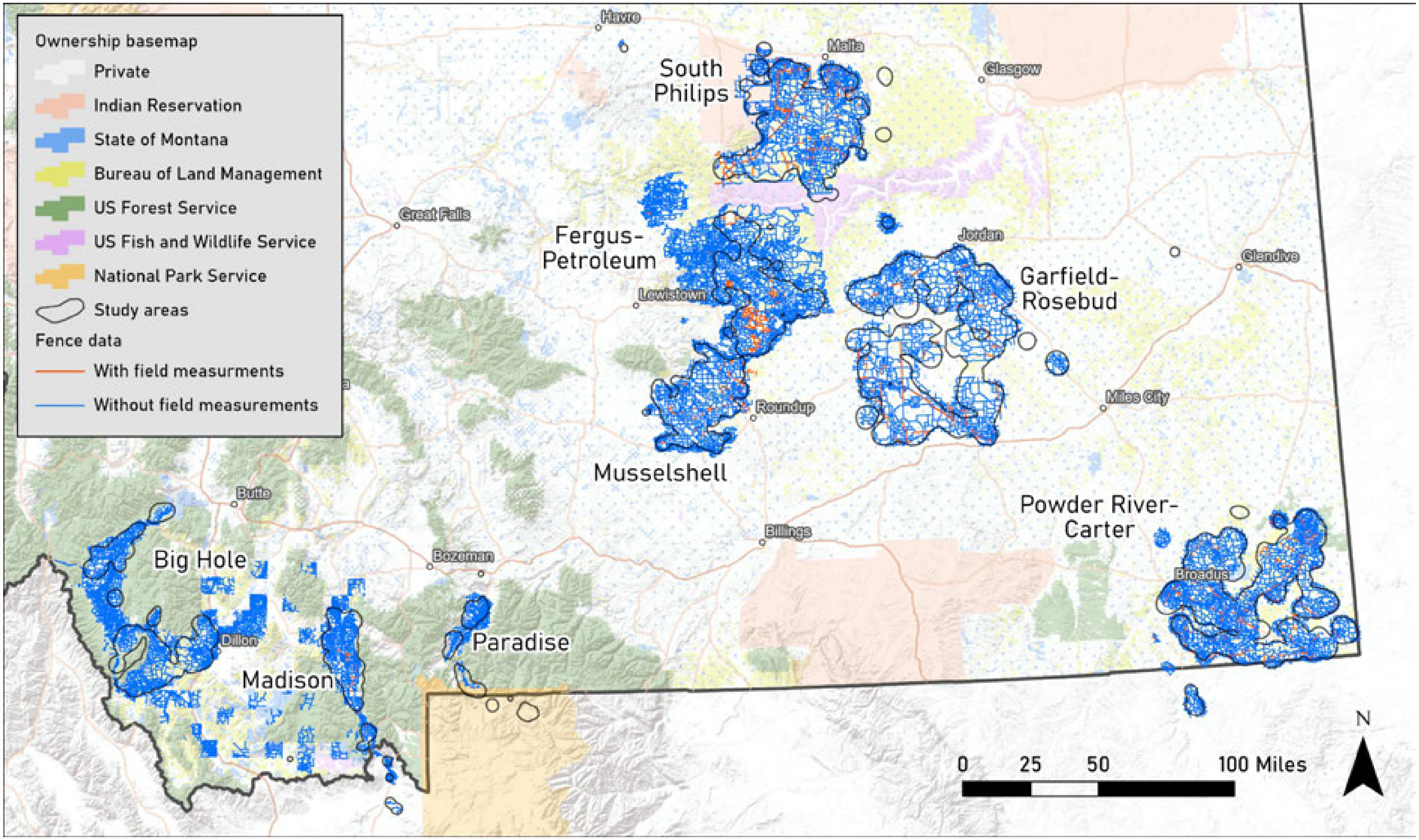


Figure 56. Fence spatial data collected as part of the Montana Pronghorn Movement and Population Ecology Project. Red and blue lines represent mapped fences with and without fence characteristics measured in the field, respectively. Black-bordered polygons represent the annual range of collared pronghorn in each study area.

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 ranked and mapped fences based on relative levels of altered fence encounters of collared pronghorn (Section 3.1.3). In addition, we evaluated the effects of different fence types on pronghorn movement behaviors (DeVoe et al. 2022; Section 3.2).

Fence permeability analysis & interactive maps

The interactive map for displaying fence permeabilities based on 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 in each study area. The tool uses the Barrier Behavior Analysis (Xu et al. 2021*b*) to identify pronghorn encounters with fence segments and categorize their subsequent movement responses into behavioral types (Figure 57). The BaBA method defines encounters based on collar locations that occur within a user-specified buffer distance from the fence segments. We specified this buffer as 50 m, which we considered to represent a distance that pronghorn may perceive and interact with a fence. Although Xu et al. determined a 110 m buffer to be optimal for 2-hour fix interval data, we considered 50 m adequate given our finer fix interval data of 1-hour (DeVoe et al. 2022). Regardless of the chosen buffer, if the start or end points (collar locations) of an individual pathway feature do not occur within the buffer of the fence, these will not be identified as an encounter or a crossing. The BaBA method categorizes movement responses to fence encounters into 7 behavior types that include: *quick cross* (animal quickly crosses the fence), *average movement* (animal does not notably change its movement pattern), *bounce* (animal moves quickly away from the fence), *back-and-forth* (animal moves back and forth along the fence), *trace* (animal moves parallel to the fence), *trapped* (animal is located constantly near a fence), and *unknown* (unable to classify movement response). These behavioral types were then classified into unaltered (i.e., quick cross and average movement) and altered (i.e., bounce, back and forth, trace, and trapped) encounter types. We used the barrier ranking tool provided as part of the BaBA framework to calculate the relative permeability of each fence segment based on the number of encounters of each behavior type and the number of unique individuals encountering the fence segment. Specifically, the barrier ranking tool calculates a permeability index representing the ratio of altered encounters (i.e., bounce, back-and-forth, trace, and trapped) to total encounters weighted by the number of unique individuals encountering the fence segment (Figure 58). The index value is then scaled between 0 and 1 using the values of all fence segments in the study area, with values closer to 1 representing a higher relative barrier effect (i.e., lower permeability) for a given fence segment. Fence segments with no encounters are not included in this calculation. It is important to note that although the index value is adjusted based on the number of unique animals encountering the fence segment, the values are sensitive to the sample size and distribution of collared pronghorn in the area. In addition, the index values are sensitive to the spatial accuracy, lengths, and distribution of the drawn fence segments. Lastly, because index values are relative to encounters occurring within the study area, index values cannot be compared across study areas. Therefore, caution must be used when interpreting the results from this tool and we suggest its use to be in combination with local knowledge of the landscape and other resources to guide prioritization of projects. The interactive maps have been developed for each study area (Figures 59 – 66 displaying the static versions) and provided to FWP wildlife management staff.

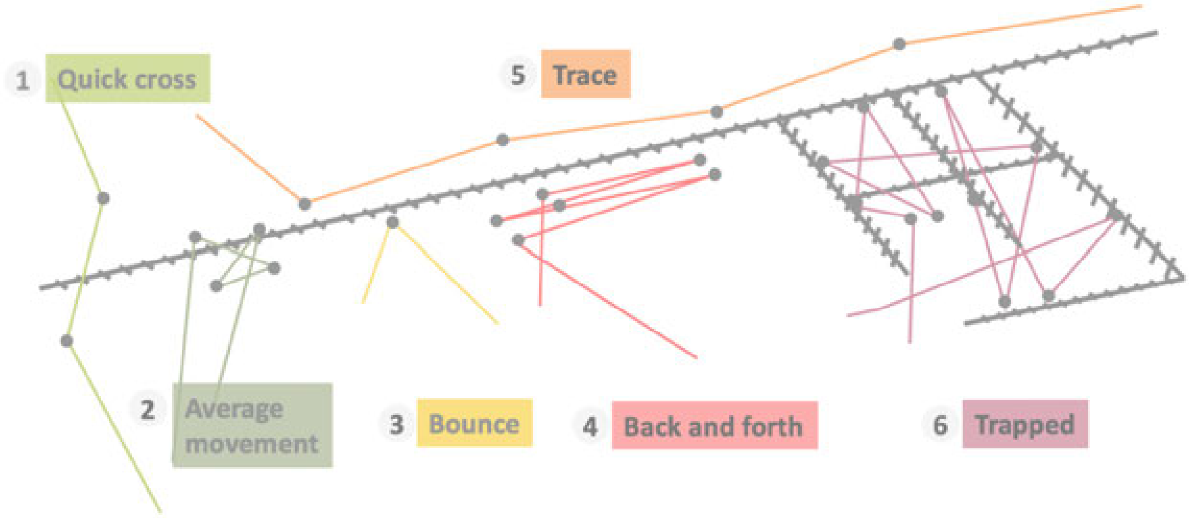
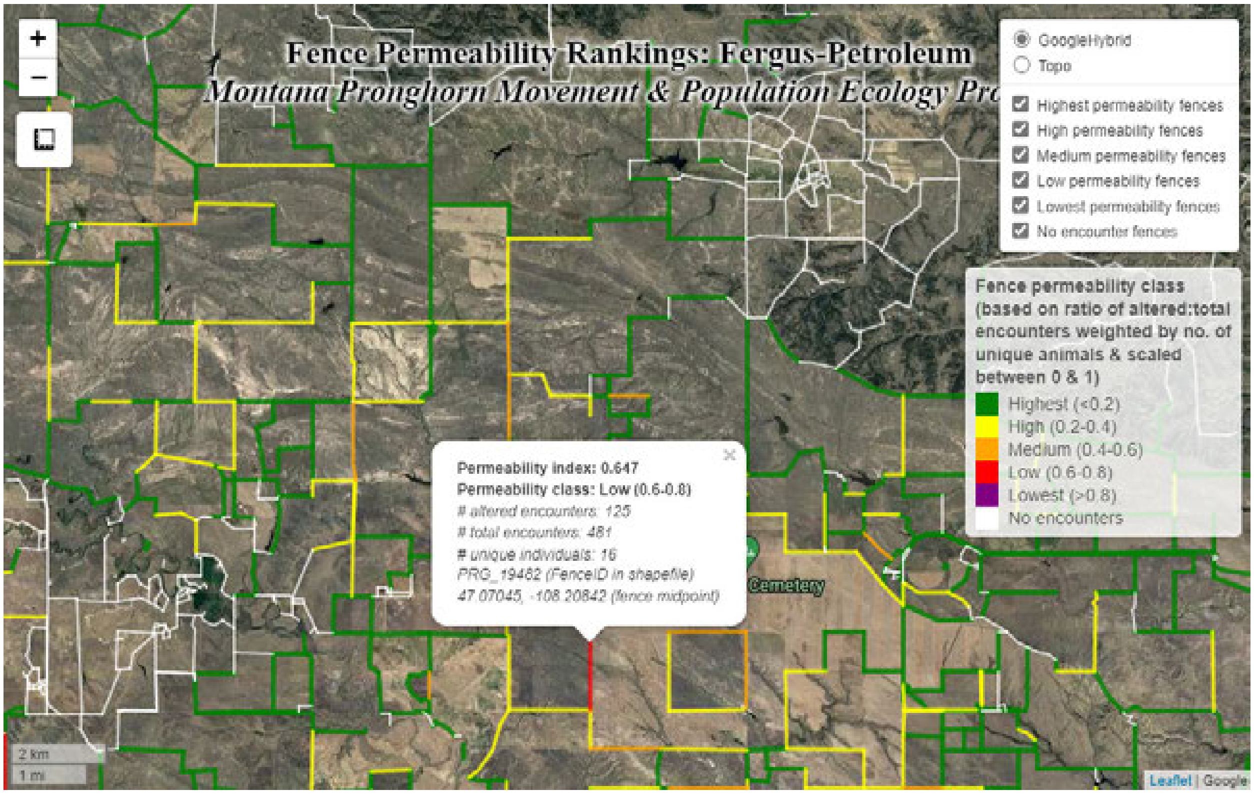


Figure 57. Schematic diagram reproduced from Xu et al. (2021*b*) showing 6 behavioral types identified in the Barrier Behavioral Analysis. Behavioral types are then classified into unaltered (i.e., quick cross and average movement) and altered (i.e., bounce, back and forth, trace, and trapped) to calculate fence segment permeability values.



Permeability index: 0.647
Permeability class: Low (0.6-0.8)
 # altered encounters: 125
 # total encounters: 481
 # unique individuals: 16
PRG_19482 (FenceID in shapefile)
47.07045, -108.20842 (fence midpoint)

Figure 58. Screenshot of the fence permeability analysis interactive map displaying mapped fences by levels of permeability based on encounters and responses of collared pronghorn. Permeably classes were categorized based on equal quantiles, and do not represent any statistically significant quantification of permeabilities.

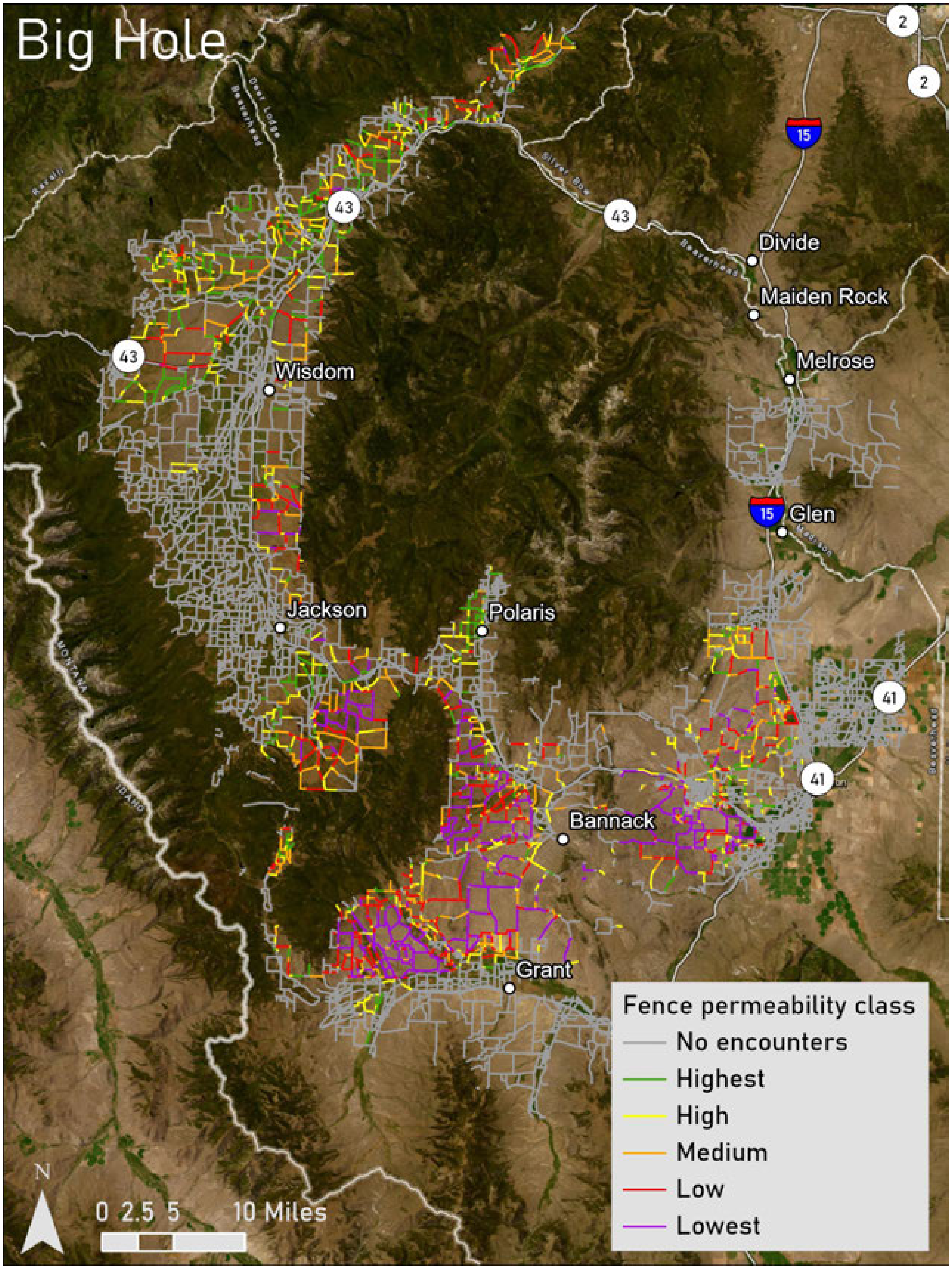


Figure 59. Fence permeability classes based on encounters and responses of collared pronghorn to fence segments in the Big Hole study area. Higher levels of permeability indicate fences with relatively fewer altered behavioral responses by collared pronghorn. Movement data collected from January 2020 to June 2023 as part of the Montana Pronghorn Movement and Population Ecology Project.

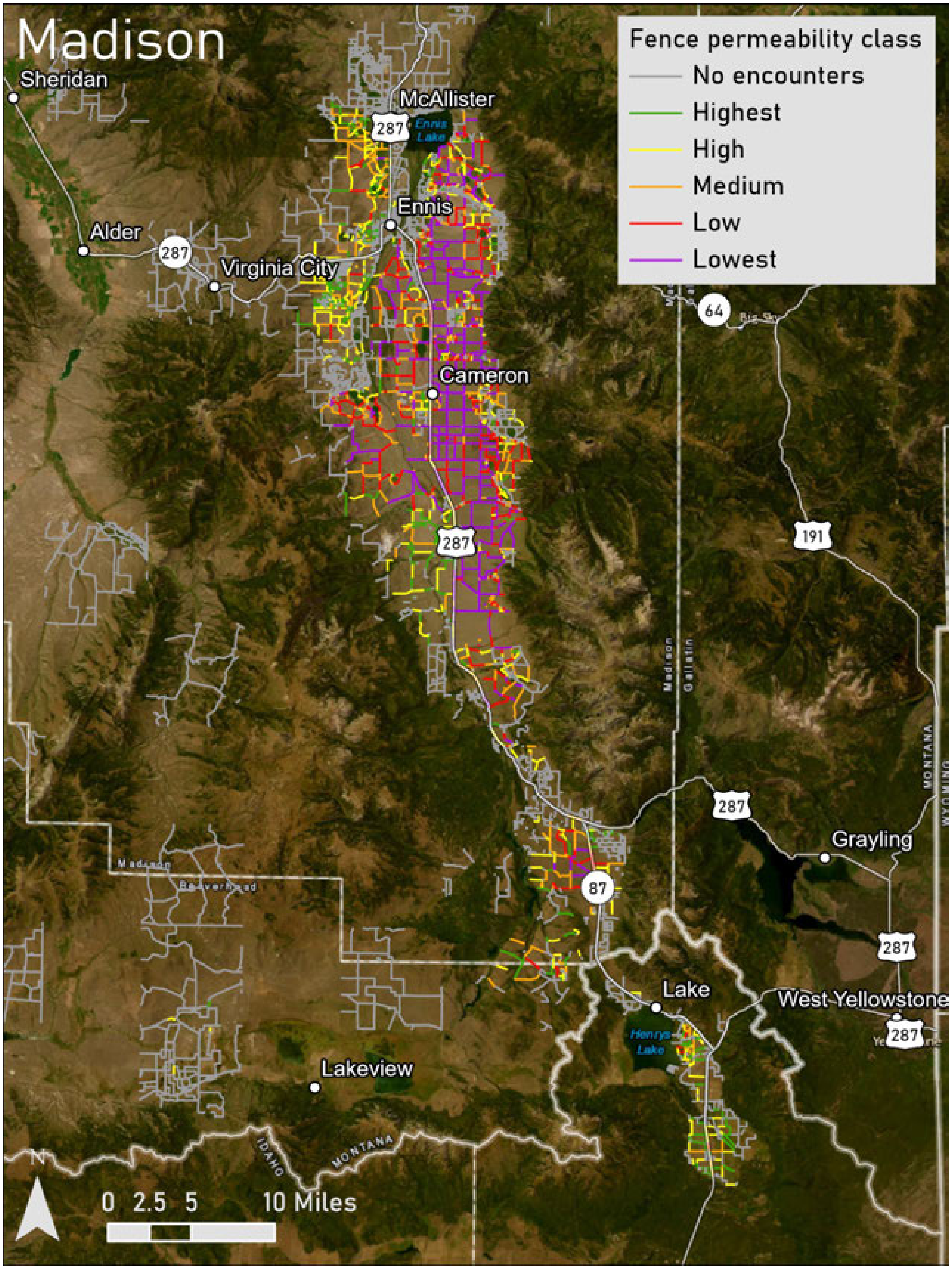


Figure 60. Fence permeability classes based on encounters and responses of collared pronghorn to fence segments in the Madison study area. Higher levels of permeability indicate fences with relatively fewer altered behavioral responses by collared pronghorn. Movement data collected from January 2020 to June 2023 as part of the Montana Pronghorn Movement and Population Ecology Project.

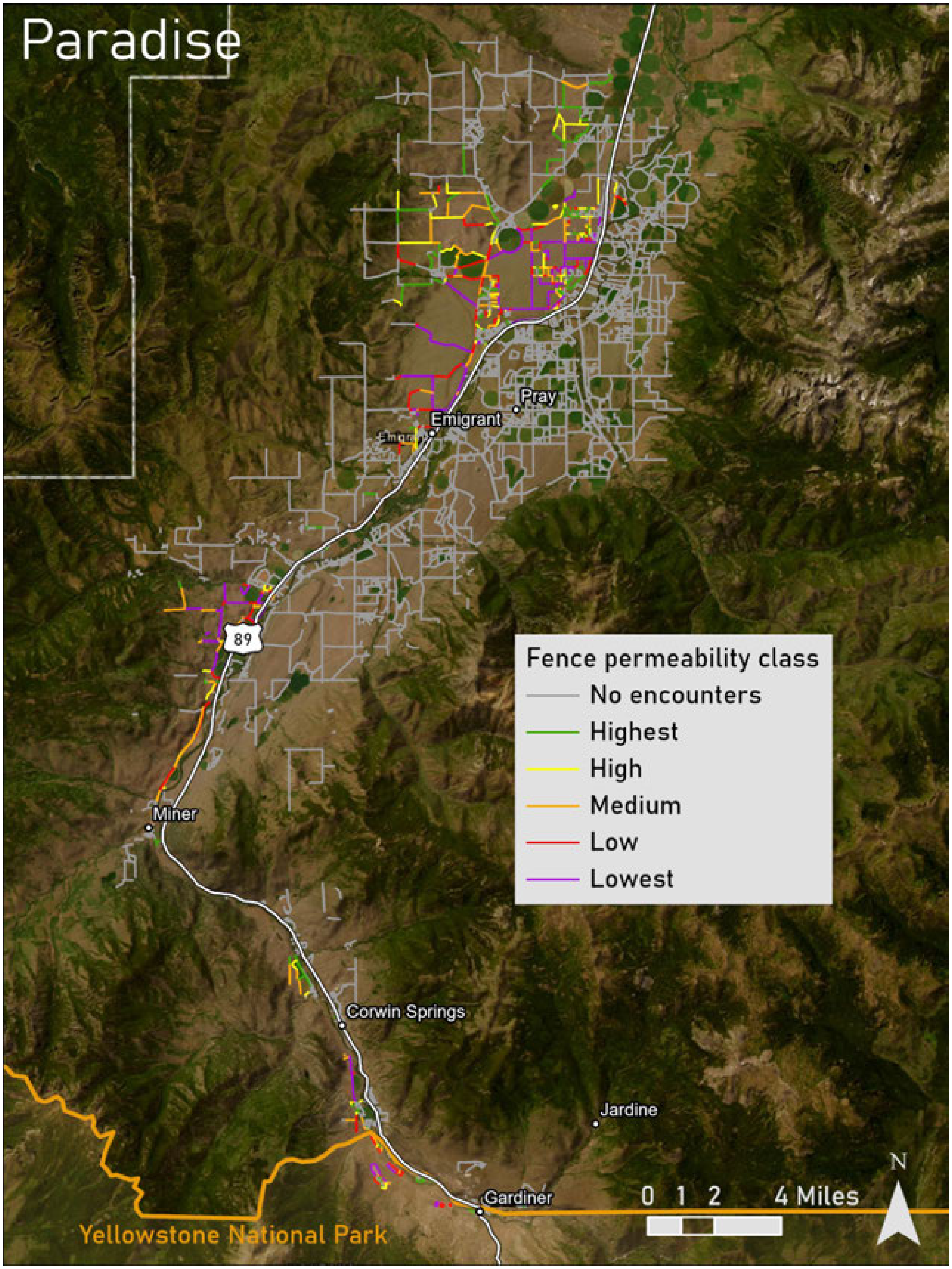


Figure 61. Fence permeability classes based on encounters and responses of collared pronghorn to fence segments in the Paradise study area. Higher levels of permeability indicate fences with relatively fewer altered behavioral responses by collared pronghorn. Movement data collected from January 2020 to June 2023 as part of the Montana Pronghorn Movement and Population Ecology Project.

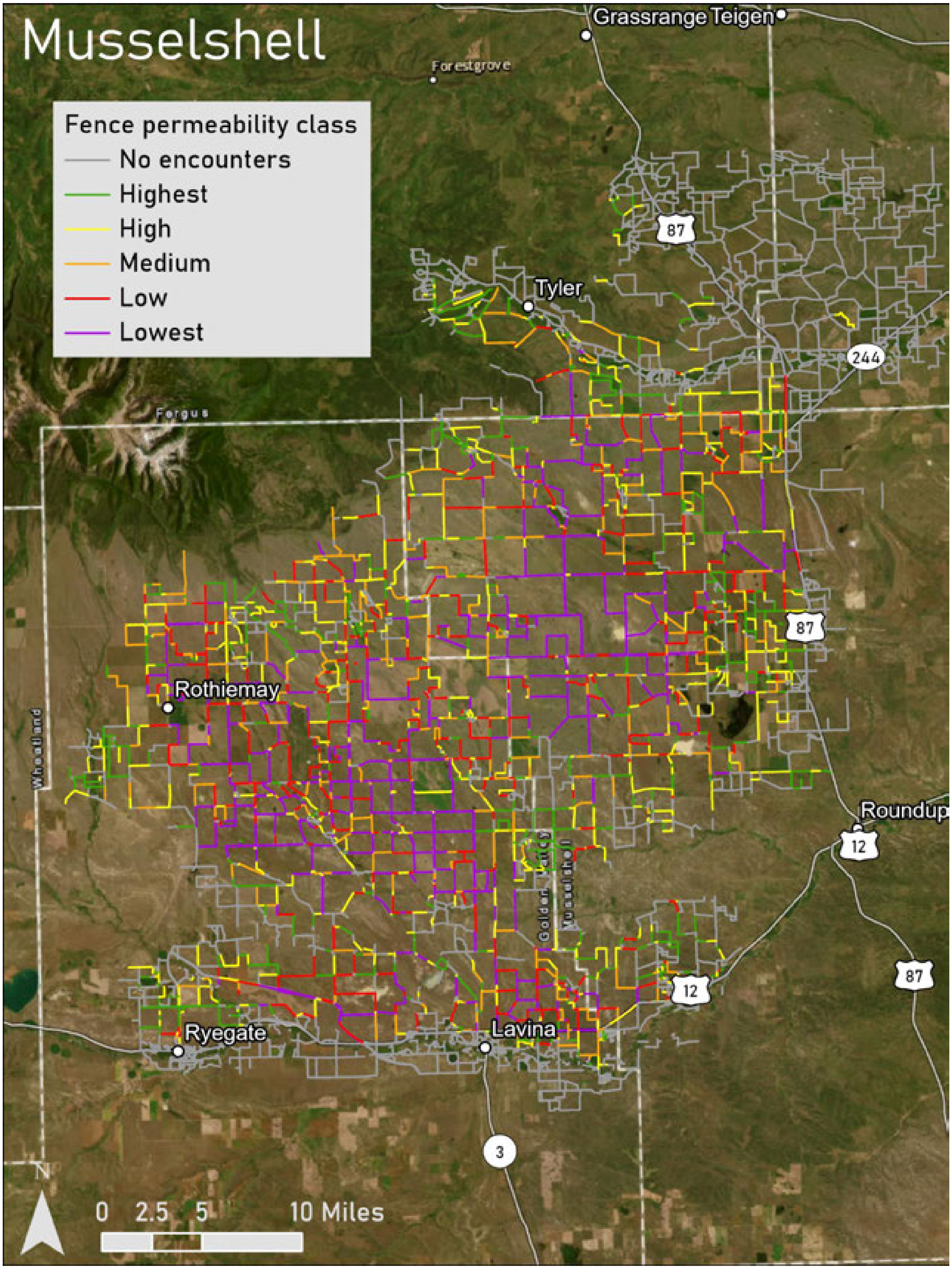


Figure 62. Fence permeability classes based on encounters and responses of collared pronghorn to fence segments in the Musselshell study area. Higher levels of permeability indicate fences with relatively fewer altered behavioral responses by collared pronghorn. Movement data collected from January 2020 to June 2023 as part of the Montana Pronghorn Movement and Population Ecology Project.

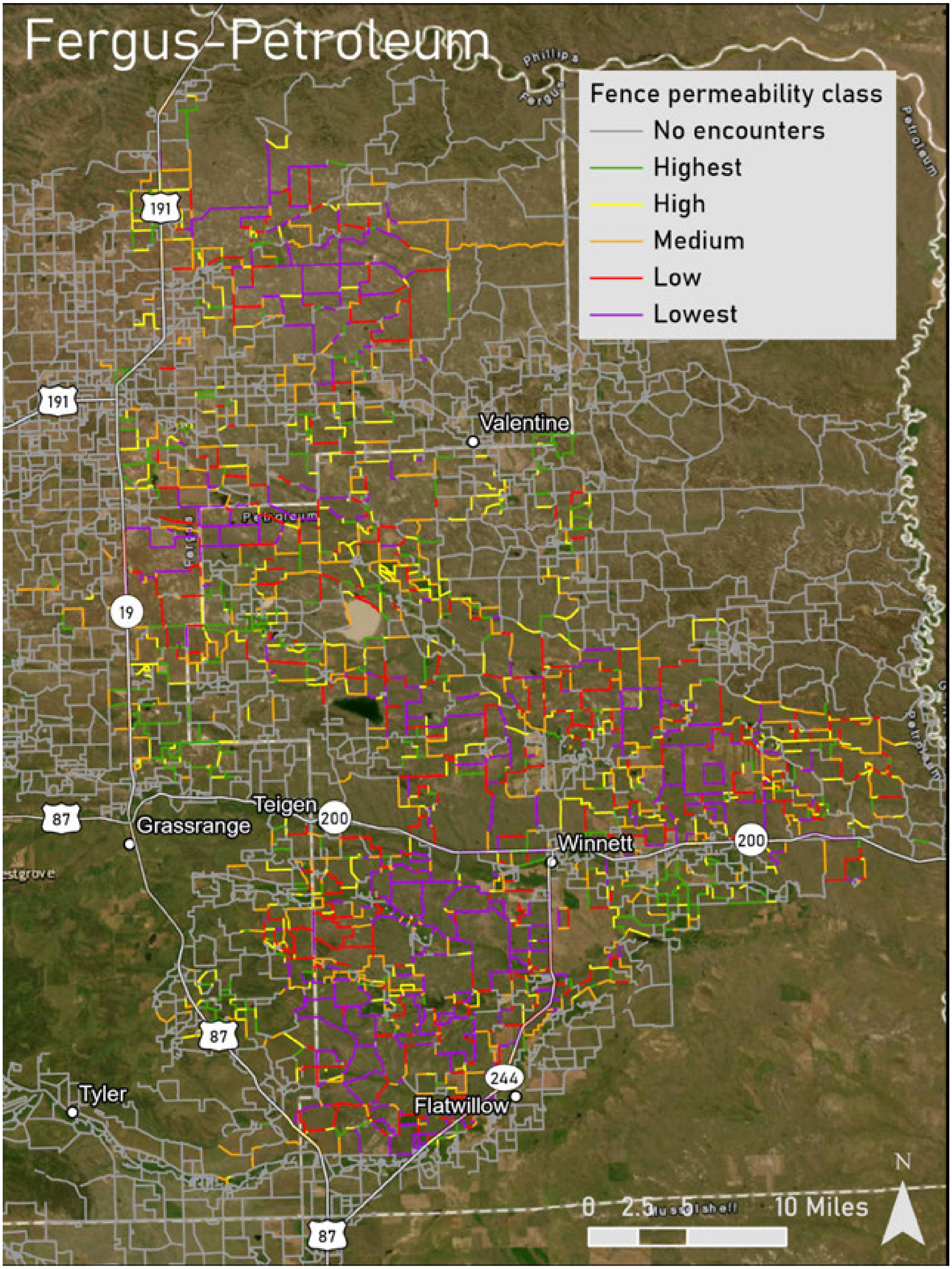


Figure 63. Fence permeability classes based on encounters and responses of collared pronghorn to fence segments in the Fergus-Petroleum study area. Higher levels of permeability indicate fences with relatively fewer altered behavioral responses by collared pronghorn. Movement data collected from January 2020 to June 2023 as part of the Montana Pronghorn Movement and Population Ecology Project.

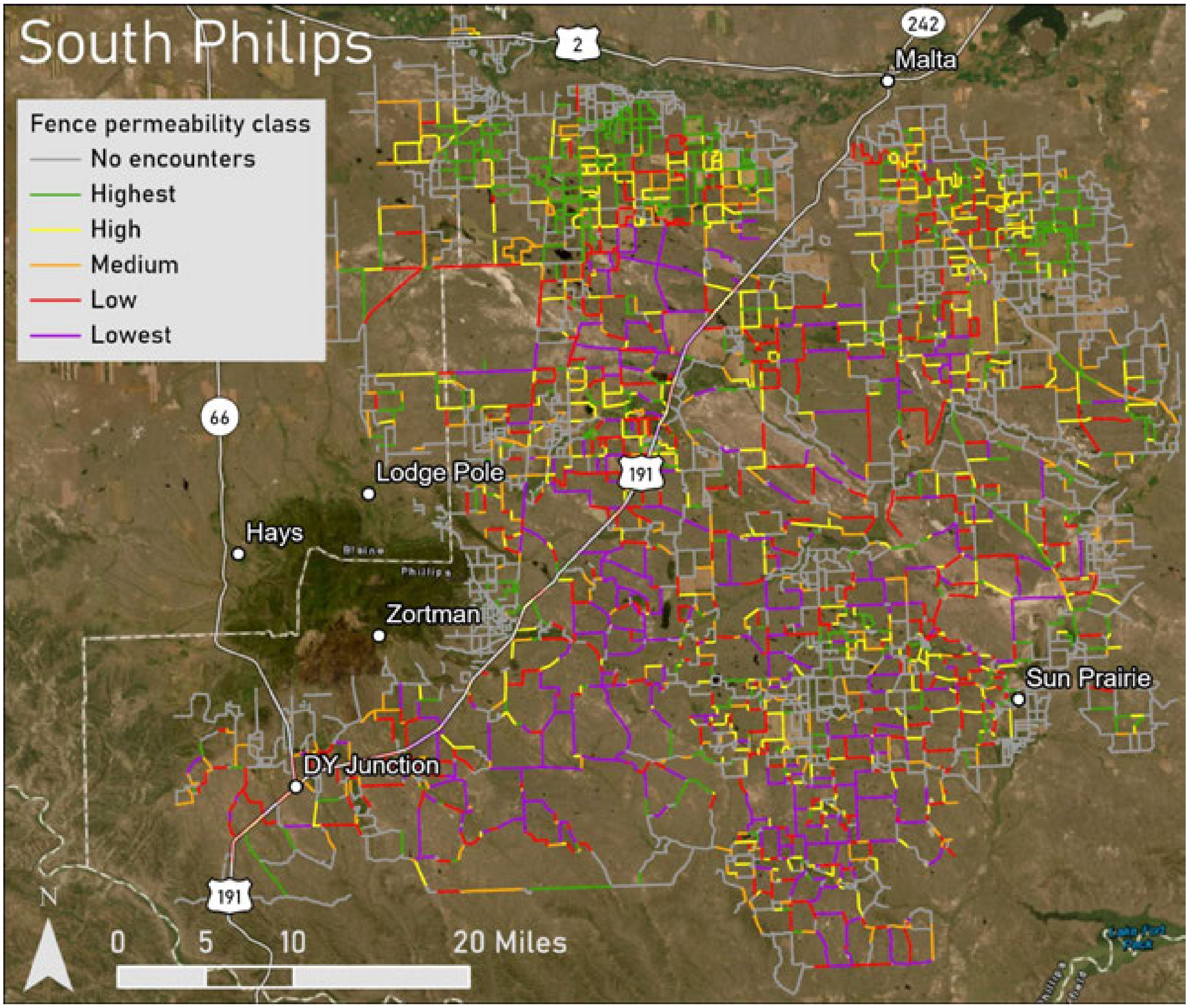


Figure 64. Fence permeability classes based on encounters and responses of collared pronghorn to fence segments in the South Philips study area. Higher levels of permeability indicate fences with relatively fewer altered behavioral responses by collared pronghorn. Movement data collected from January 2020 to June 2023 as part of the Montana Pronghorn Movement and Population Ecology Project.

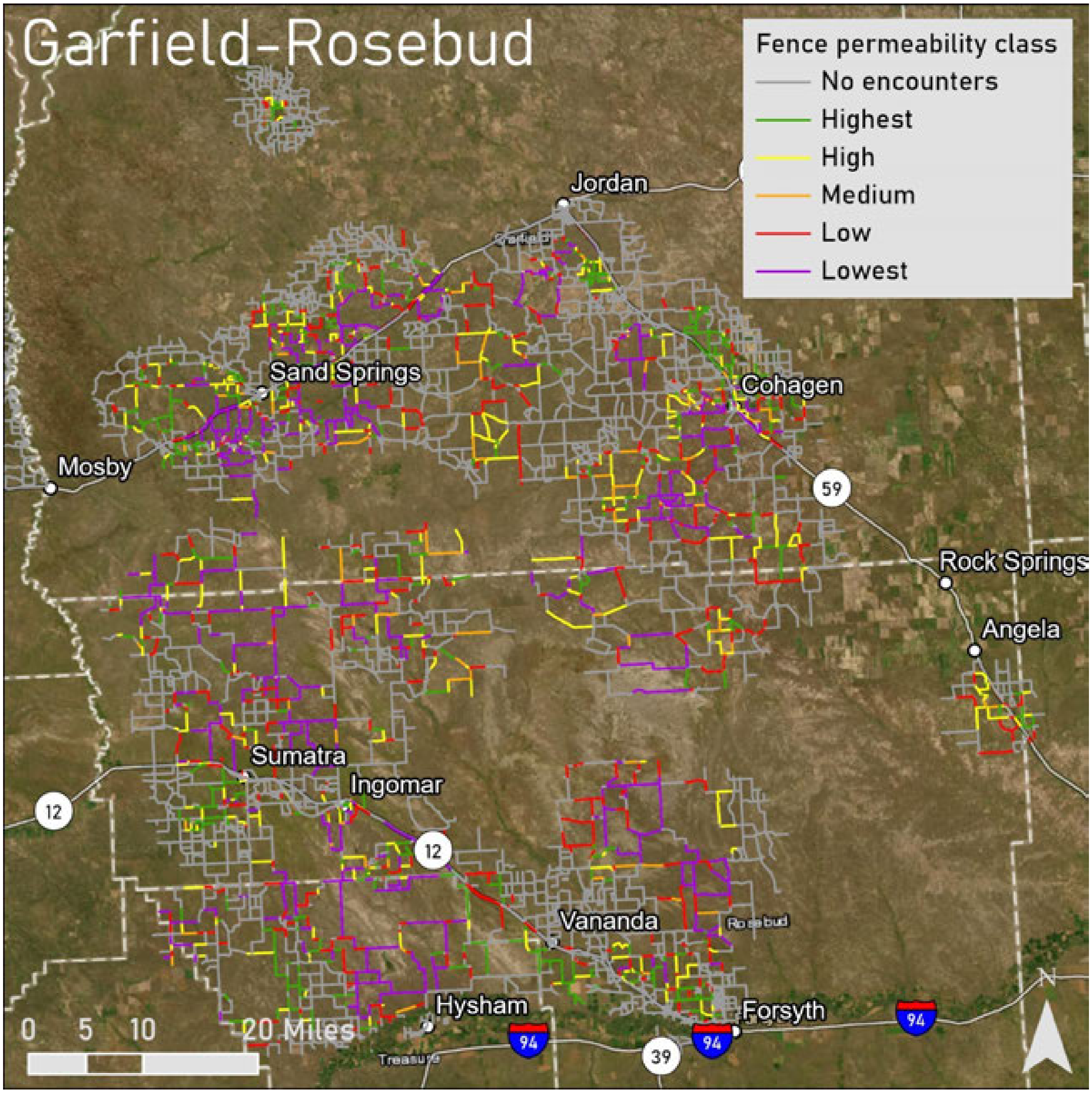


Figure 65. Fence permeability classes based on encounters and responses of collared pronghorn to fence segments in the Garfield-Rosebud study area. Higher levels of permeability indicate fences with relatively fewer altered behavioral responses by collared pronghorn. Movement data collected from January 2020 to June 2023 as part of the Montana Pronghorn Movement and Population Ecology Project.

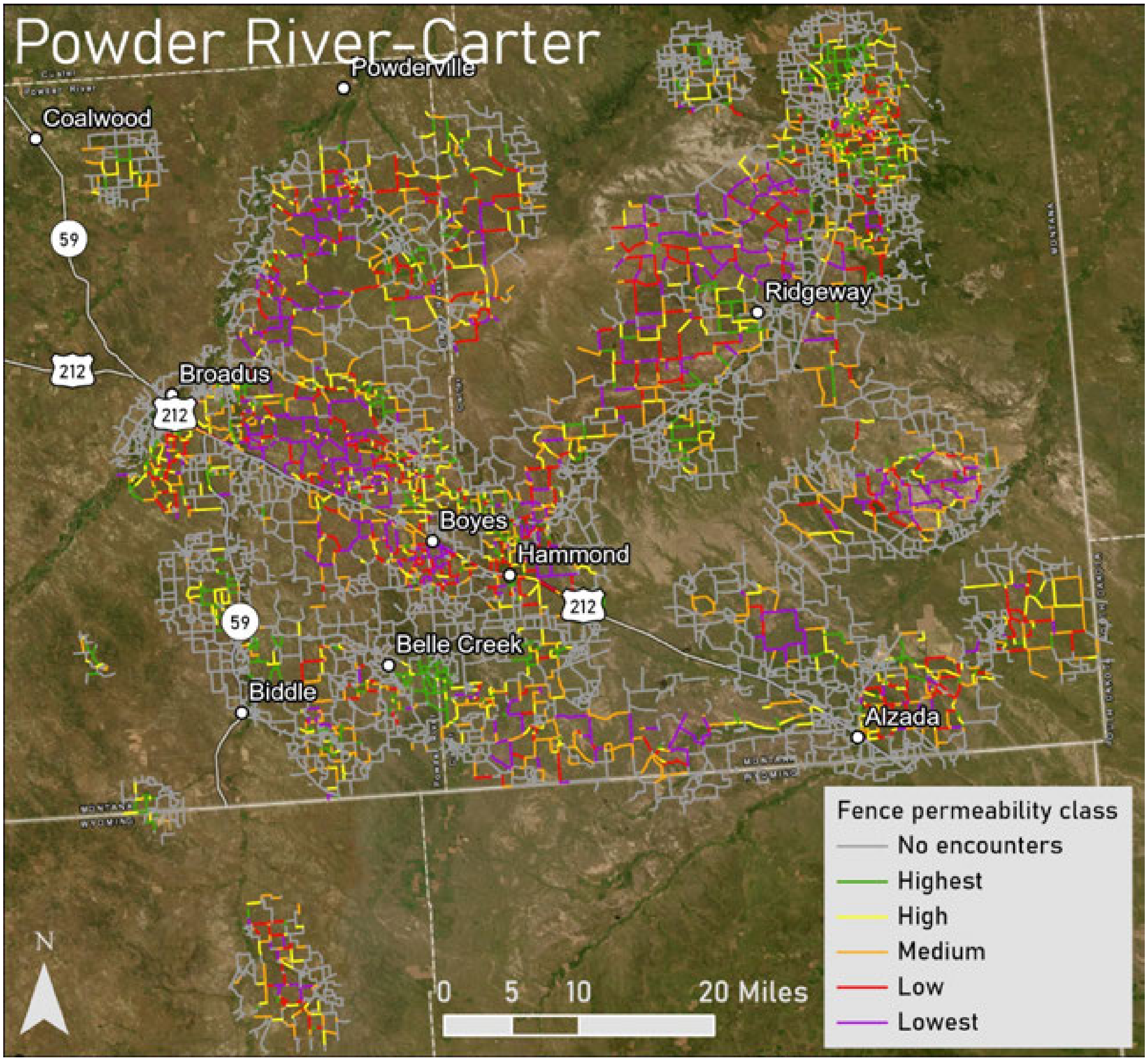


Figure 66. Fence permeability classes based on encounters and responses of collared pronghorn to fence segments in the Powder River-Carter study area. Higher levels of permeability indicate fences with relatively fewer altered behavioral responses by collared pronghorn. Movement data collected from January 2020 to June 2023 as part of the Montana Pronghorn Movement and Population Ecology Project.

3.2 Evaluating the effect of varying fence types on pronghorn movement 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 published as a research article in the peer-review journal Ecosphere (DeVoe et al. 2022). 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 6 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. (2021*b*) to evaluate 3 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 3 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 67). 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 14 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.

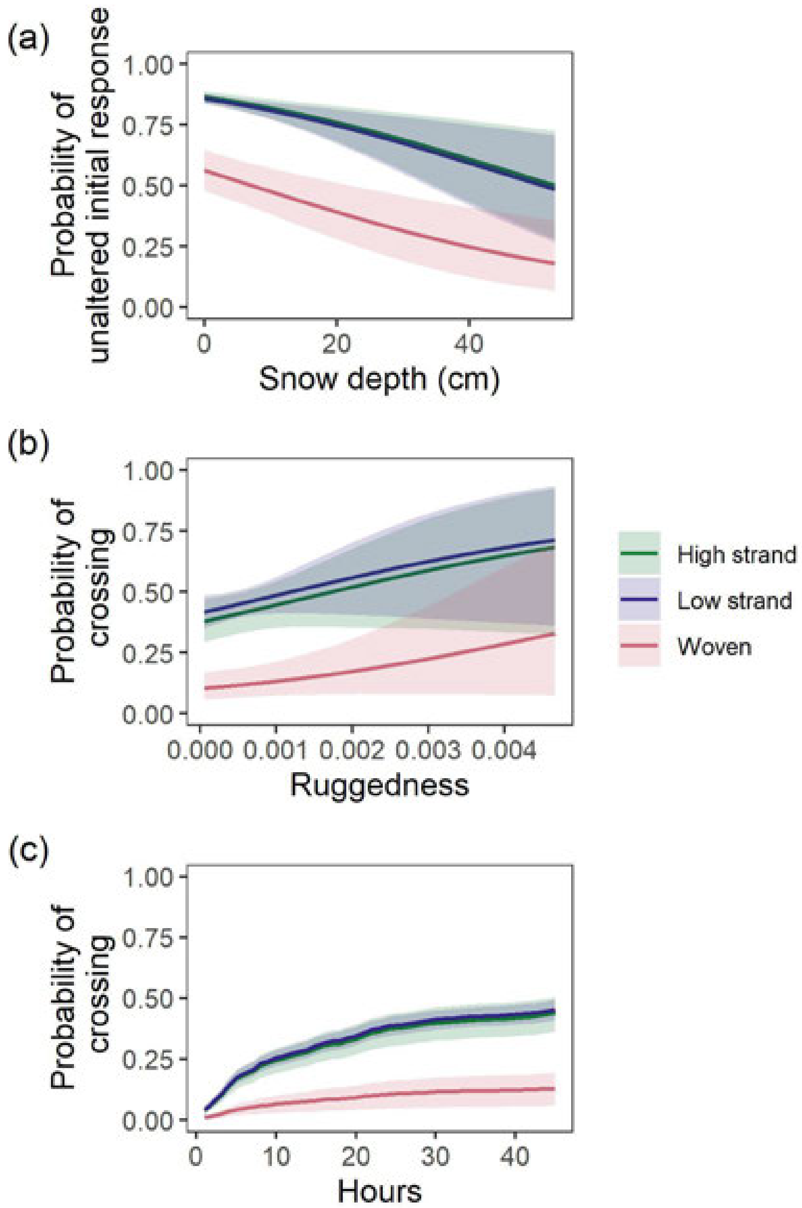


Figure 67. Predicted relationships of the probability (±95% CI) of unaltered initial response (panel a), probability of crossing following an altered initial response (panel b), and passage time (i.e., probability of crossing through time) following an altered initial response (panel c) of pronghorn 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. Reproduced from DeVoe et al. (2022).

3.3 Collaborative efforts to remediate movement barriers

Biologists from multiple organizations have used 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 68 – 69; Table 9). In total, 31 projects have been completed (totaling 86 miles), 5 are ongoing (totaling 22 miles), and 12 are in preparation (totaling 33 miles). In addition to the multi-agency partnerships to accomplish individual projects, FWP biologists have presented the collar movement and fence barrier information in various meetings with stakeholders, including other state and federal agencies, city and county commissioners, non-profit groups, and individual landowners.

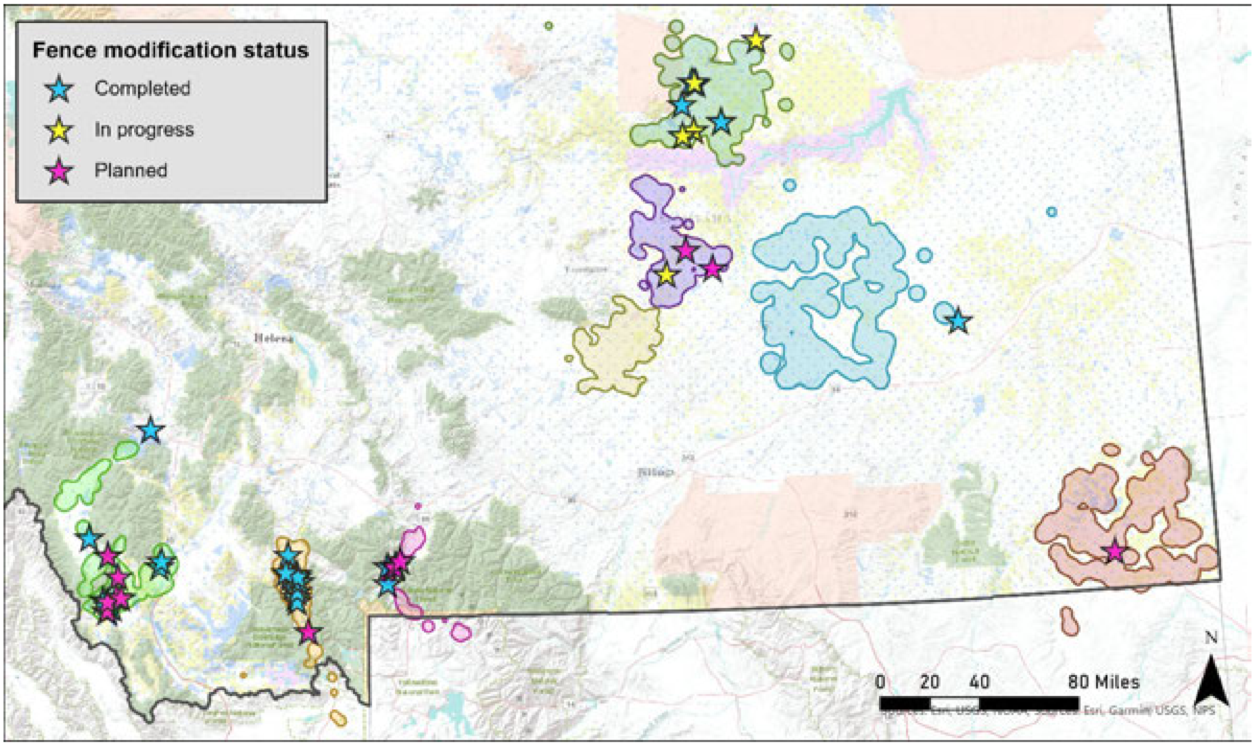


Figure 68. Locations of planned, in progress, and completed fence modification efforts informed by the pronghorn collar movement data collected as part of the Montana Pronghorn Movement and Population Ecology Project. Annual range polygons of the 8 study areas are shown overlaid on land ownership.

Wildlife Friendly Fencing

This land is being managed with wildlife friendlier fences, allowing pronghorn, elk, mule deer and other wildlife opportunities to move through this critical wildlife migration route.

This project is possible due to collaboration between private landowners, agencies and non-profit conservation organizations.

Figure 69. 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: removing barbed-wire fences in the Madison study area (photo credit: National Parks Conservation Association). Top right photo: removing a woven wire fence in Horse Prairie of SW Montana (photo credit: FWP). Middle photo: displaying the quantity of fending removed in SW Montana (photo credit: National Wildlife Federation). Bottom left image: signage used for outreach in the Madison and Paradise study areas. Bottom right photo: modifying wires in the Madison study area (photo credit: National Parks Conservation Association).

Table 9. 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. Projects are arranged by status and completion year.

Project name	General area	Status	Completion year	Type of modification (WF = wildlife friendly)	Length (mi)	Ownership	Lead & Partner Agencies*
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
Black Mountain Ranch	Madison Valley	Completed	2020	Old: 5-strand barbed New: 4-strand WF	2.5	Private	NPCA
Granger Ranches	Madison Valley	Completed	2020	Old: 5-strand barbed New: 4-strand WF	2.5	Private	NPCA
BLM Malta Field Office 2021 MCC Project	Dry Fork Rd South Phillips	Completed	2021	Removal of bottom strands	4.5	BLM	BLM
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
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
Goggins N. Ennis	Madison Valley	Completed	2021	Old: 5-strand barbed New: 3-strand, electric lay-down	1.3	Private	NPCA
Granger Ranches	Madison Valley	Completed	2021	Old: 5-strand barbed New: 4-strand WF	1	Private	NPCA
Creek Bottom Project	SW of Malta	Completed	2021	Old: 4-strand barbed New: 4-strand WF	2.33	Private	RSA
SW MT Fencing for Wildlife Program	Big Hole	Completed	2022	Old: 4 strand barbed New: 4-strand WF	1	Private/USFS	NWF
SW MT Fencing for Wildlife Program	Frying Pan Basin	Completed	2022	Old: 6-strand barbed New: 4-strand WF	4.4	Private/BLM	NWF
SW MT Fencing for Wildlife Program	Horse Prairie	Completed	2022	Old: woven wire New: 4-strand WF	2	Private/BLM	NWF
SW MT Fencing for Wildlife Program	Horse Prairie	Completed	2022	Old: woven wire New: 4-strand WF	1	Private/BLM	NWF
Granger Ranches	Madison Valley	Completed	2022	Old: 5-strand barbed New: 4-strand WF	1	Private	NPCA
GYCC West Creek	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/ WF post/rail section	0.3	Private	NPCA
GYCC Antelope Basin	Paradise Valley	Completed	2022	Old: 5-strand barbed	0.2	Private	NPCA

Project name	General area	Status	Completion year	Type of modification (WF = wildlife friendly)	Length (mi)	Ownership	Lead & Partner Agencies*
				New: WF panel configuration			
Hybrid	S of Malta	Completed	2022	Old: woven wire New: 4-strand WF	4.35	Private	RSA
Hybrid	S of Malta	Completed	2022	Removal of woven wire	5.3	Private	RSA
Outcome Based Grazing Fence Mods Phase 1	SW of Winnett	Completed	2022	Old: 5-strand barbed New: 4-strand WF	2.5	Private/BLM	BLM/Permittee
Willow Creek Addition to Mt Haggin WMA	Anaconda	Completed	2023	Modification to WF wire heights	1.5	FWP	FWP
Willow Creek Addition to Mt Haggin WMA	Anaconda	Completed	2023	Removal of 4-5 strand barbed	4.5	FWP	FWP
SW Montana Fencing for Wildlife Program	Horse Prairie	Completed	2023	Old: 5-strand barbed New: 4-strand WF	1.5	Private/BLM	NWF
Dierking	Madison Valley	Completed	2023	Removal of bottom strand	2	Private	NPCA/FWP
Granger Ranches	Madison Valley	Completed	2023	Removal of 5-strand barbed	0.2	Private	NPCA
Granger Ranches	Madison Valley	Completed	2023	Removal of 5-strand barbed	0.4	Private	NPCA
North Sunday Creek	N of Miles City	Completed	2023	Old: woven wire New: removed/modified to 4-strand WF	15.5	Private/BLM	FWP
Smith	Paradise Valley	Completed	2023	Replaced 3 strand electric	0.6	Private	NPCA
S. Phillips Project (LBWR)	SW of Malta	Completed	2023	Old: 4-strand barbed New: 4-strand WF	9.42	Private	RSA
Chinook Winds Project	SW of Malta	Completed	2023	Old: woven wire New: 4-strand WF	6	TNC	RSA
Granger Ranches	Madison Valley	Completed	2024	Modified to 4-strand WF	0.8	Private	NPCA
Granger Ranches	Madison Valley	Completed	2024	Modified to 2-strand WF	1	Private	NPCA
Chief	S of Bowdoin	In progress	2024	Old: 4-strand barbed New: 4-strand WF	5	BLM/private	RSA
Turbine Project	SW of Malta	In progress	--	Old: 4-strand barbed New 4-strand WF	2.25	Private	RSA
FlyBoy Project	SW of Malta	In progress	--	Modify to WF wire heights	8	Private	RSA
Carter & Powder River Highway Projects	Hwys 59/212/323	Planned	2024	Replace bottom wires w/ smooth wire or clipping bottom 2 wires	TBD	Varied	FWP/MDT
SW MT Fencing for Wildlife Program	Grasshopper Valley/Hwy 278	Planned	2024	Old: Woven wire, 5- & 6-strand barbed New: Remove/replace to 4-strand WF	4.95	Private/BLM/ DNRC	NWF
SW MT Fencing for Wildlife Program	Horse Prairie	Planned	2024	Old: Woven wire & 5-strand barbed New: 4-strand WF	1	DNRC	NWF

Project name	General area	Status	Completion year	Type of modification (WF = wildlife friendly)	Length (mi)	Ownership	Lead & Partner Agencies*
SW MT Fencing for Wildlife Program	Horse Prairie	Planned	2024	Old: Woven wire New: 4-strand WF	2	Private	NWF
SW MT Fencing for Wildlife Program	Horse Prairie	Planned	2024	Old: Woven wire, 5-, & 6-strand barbed New: Remove/replace to 4-strand WF	2	Private/DNRC	NWF
Antelope Basin Ranch	Paradise Valley	Planned	2024	Old: 5-strand barbed New: 3 rail WF post/rail	0.6	Private	NPCA
Waggoner	Paradise Valley	Planned	2024	Remove 4-strand barbed	TBD	Private	NPCA/Landowners
Restoration Landscape WF Fence Phase 1	Reservoir Crk/Badger	Planned	2024	Old: woven wire New: 4-strand (2 barbed, 2 smooth)	17	BLM	BLM
Papoose Creek	Madison Valley	Planned	2024/25	Old: 4- & 5-strand barbed New: 4-strand WF	1.7	Public/USFS	NPCA
Carroll Hill	Big Hole	Planned	--	Old: 5-strand barbed New 4-strand WF	1	Private/USFS	NWP
Marks Individual Fence Mods Phase 1	N of Winnett	Planned	--	Old: 5-strand barbed New 4-strand WF	2	BLM	BLM/Permittee
RCPP Fence (Solf Bros B.)	SE of Winnett	Planned	--	Old: 5-strand barbed New 4-strand WF	0.75	Private/BLM	BLM/NRCS/ Permittee

**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

Background & objectives

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 population abundance and improve inferences into the underlying drivers of variation of these processes (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, while 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 classification surveys and harvest data collected for each study area (Figure 70). We are using a state-space IPM approach, wherein the model consists of a biological process model and an observation model (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.

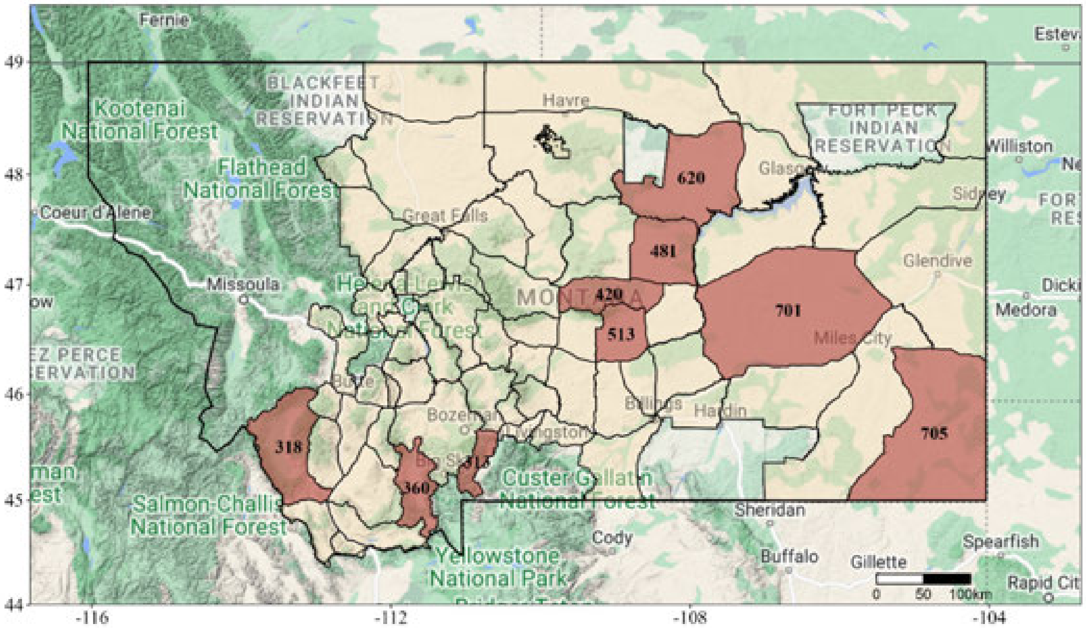


Figure 70. The nine pronghorn hunting districts (shaded red) within the pronghorn study areas included in the integrated population model for the Pronghorn Movement and Population Ecology Project.

Methods

Process model and vital rates

We defined a pronghorn ecological year from 01 Oct of year t to 30 Sep of year t+1 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 (Figure 71). We chose to use the beginning of the pronghorn 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: 0–4 months, juvenile: 4–16 months, and adult: 16+ months. Fawns advance to the juvenile age class immediately 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 FWP stores fall harvest data (2 stages, 2 sexes).

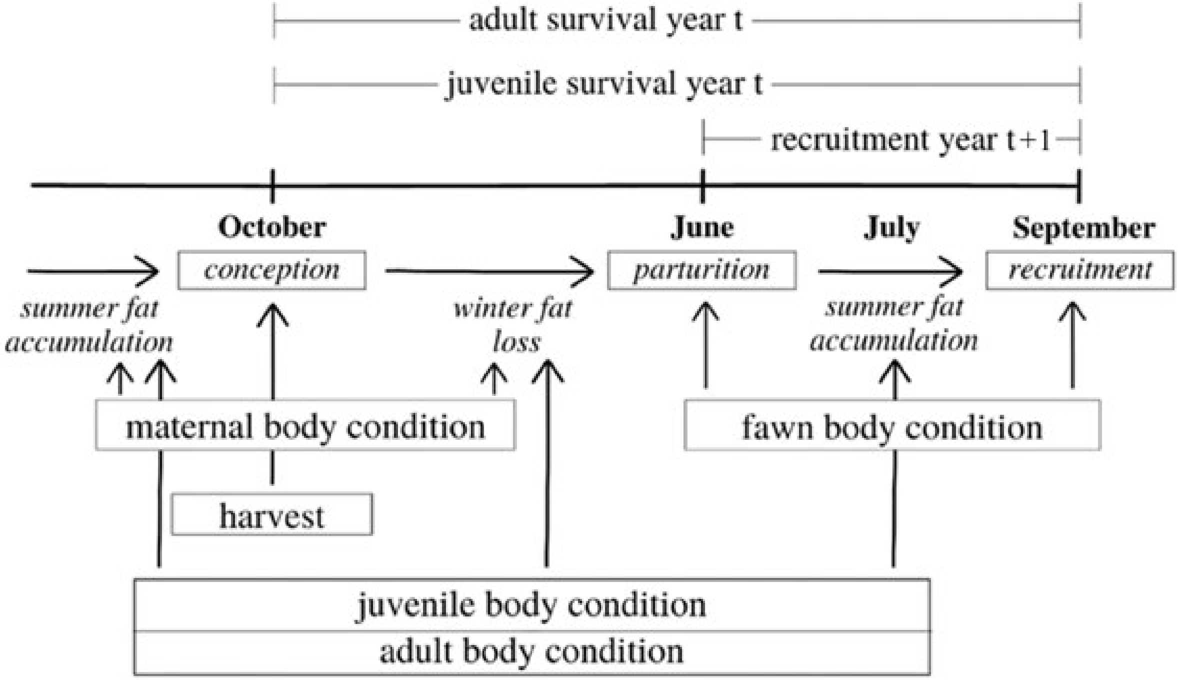


Figure 71. Conceptual diagram explaining the ecological year experienced by pronghorn and associated covariates in our survival (juvenile and adult) and recruitment process models. Model year is 01 Oct year t to 30 Sep year t+1, where fawn and adult count and ratio surveys occur in July after parturition, and adult and juvenile harvest occurs in October. Age classes are defined as fawn: 0–4 months, juvenile: 4–16 months, and adult: 16+ 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. Note: we define recruitment in the model as occurring 4 months after birth.

The biological process model is a discrete time (i.e., 01 Oct of year t to 30 Sep of year t+1), 3-stage (i.e., fawn, juvenile, adult) and 2-sex (i.e., male, female) matrix projection model. We assumed that fawns were recruited into the juvenile age class on October 1 at a rate similar to the age-sex counts observed during July aerial surveys. We further assumed that the sex ratio at birth was equal. In this manner, we were able to use the fawn:doe ratio data collected during summer aerial surveys as a measure of reproductive output (i.e., 4-month recruitment), which better aligns the biological process with data collection (e.g., White and Lubow 2002). We included demographic stochasticity in the process model with a Poisson distribution for fawns and Binomial distribution for juveniles and adults.

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

Our recruitment and survival models examined environmental variables thought to affect pronghorn population vital rates. To account for potential lag-effects on survival and recruitment, we examined vegetation and climatic conditions from both the current and previous model year (Figure 71; Figure 72). We hypothesized 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). Thus, we included pronghorn population-level annual mean net primary productivity (NPP; MODIS Terra Net Primary Productivity: *https://lpdaac.usgs.gov/products/mod17a3hgfv006/)*, annual mean precipitation (PRISM), and winter snow depth (SNOWDAS: https://nsidc.org/data/g02158) in linear models predicting recruitment. We also included a temporal random effects structure to allow for random variation in recruitment across years.

We hypothesized that annual variation in 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*c*). Thus, we included NPP and winter snow depth in linear models predicting adult survival.

We hypothesized that harvest rate would be affected by the number of permits issued in a hunting district (i.e., "hunting effort"), so we included hunting effort in linear models predicting juvenile and adult harvest rate. Specifically, we included the number of either-sex permits issued as the hunting effort value for adult male, female, and juvenile harvest, and the total number of doe/fawn permits issued as the hunting effort value for adult female and juvenile harvest.

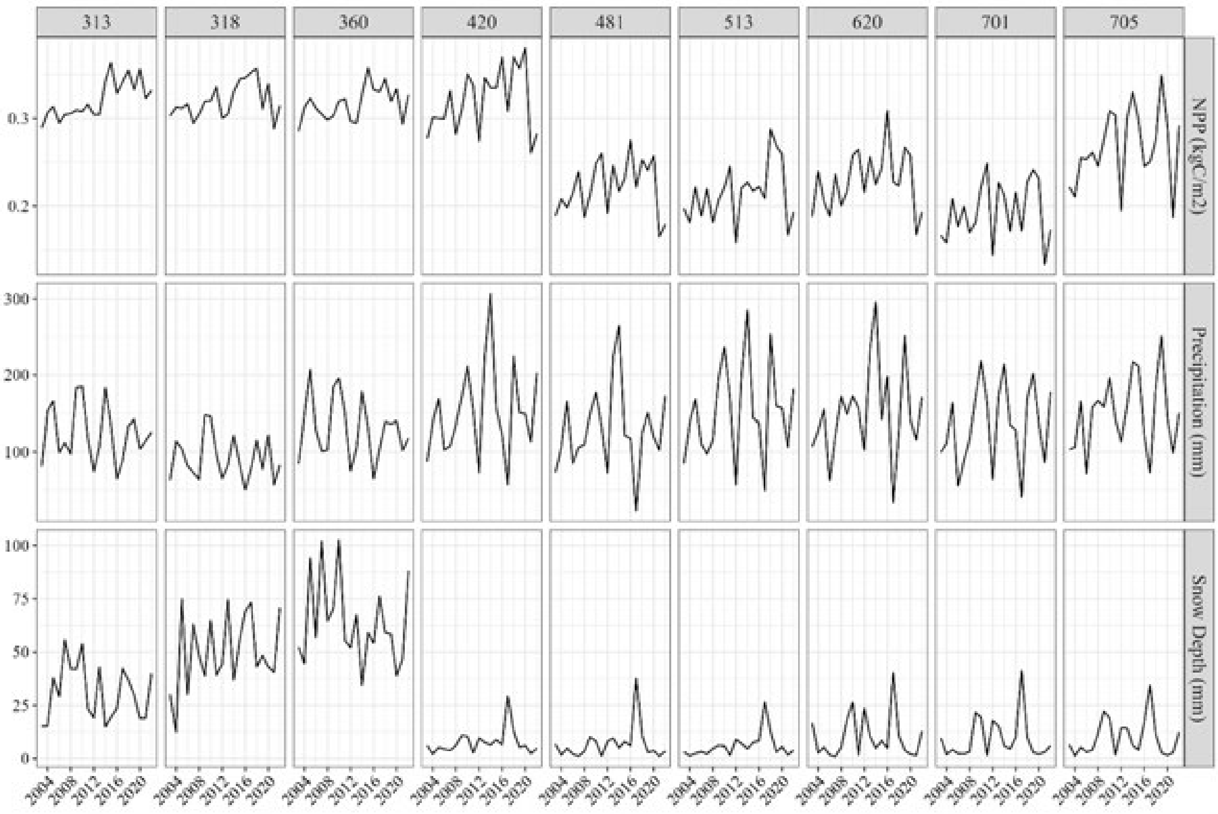


Figure 72. Net primary productivity (NPP), mean cumulative winter snow depth, and mean total summer precipitation across 9 pronghorn hunting districts in Montana from 2003 – 2021. Values were used as covariates in linear models predicting pronghorn 4-month recruitment and annual survival.

Observation models

Observation models link empirical field data to biological parameters in an IPM (Schaub and Abadi 2011). Observation data for the pronghorn IPM consisted of population counts from aerial surveys, harvest estimates from FWP harvest surveys, and survival data from collared adult females.

Aerial surveys

Pronghorn count data were collected during surveys that occurred at 2 times (winter [March] and summer [July]) of year and in 3 different structures. The first type of count data structure were total counts without age/sex information, collected through complete coverage surveys. The second type of count data were stage-structured complete counts, collected through complete coverage surveys that identified age (adult/fawn) and sex (only adults) of individuals. In most hunting districts, the stage-structured counts were considered counts of the entire population; however, in HD 360, where pronghorn movement occurs throughout the year, only the age/sex ratios from these counts were used for population monitoring. Finally, trend surveys were used to count and classify only pronghorn within trend area(s) within larger hunting districts. 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 could be used to accurately predict the total population. Mean pronghorn density from trend areas was extrapolated to the HD level using the area of pronghorn habitat delineated by the FWP pronghorn habitat layer (Figure 73, Table 10). Further details can be found in the FWP evaluation of survey protocols report (Newell 2013).

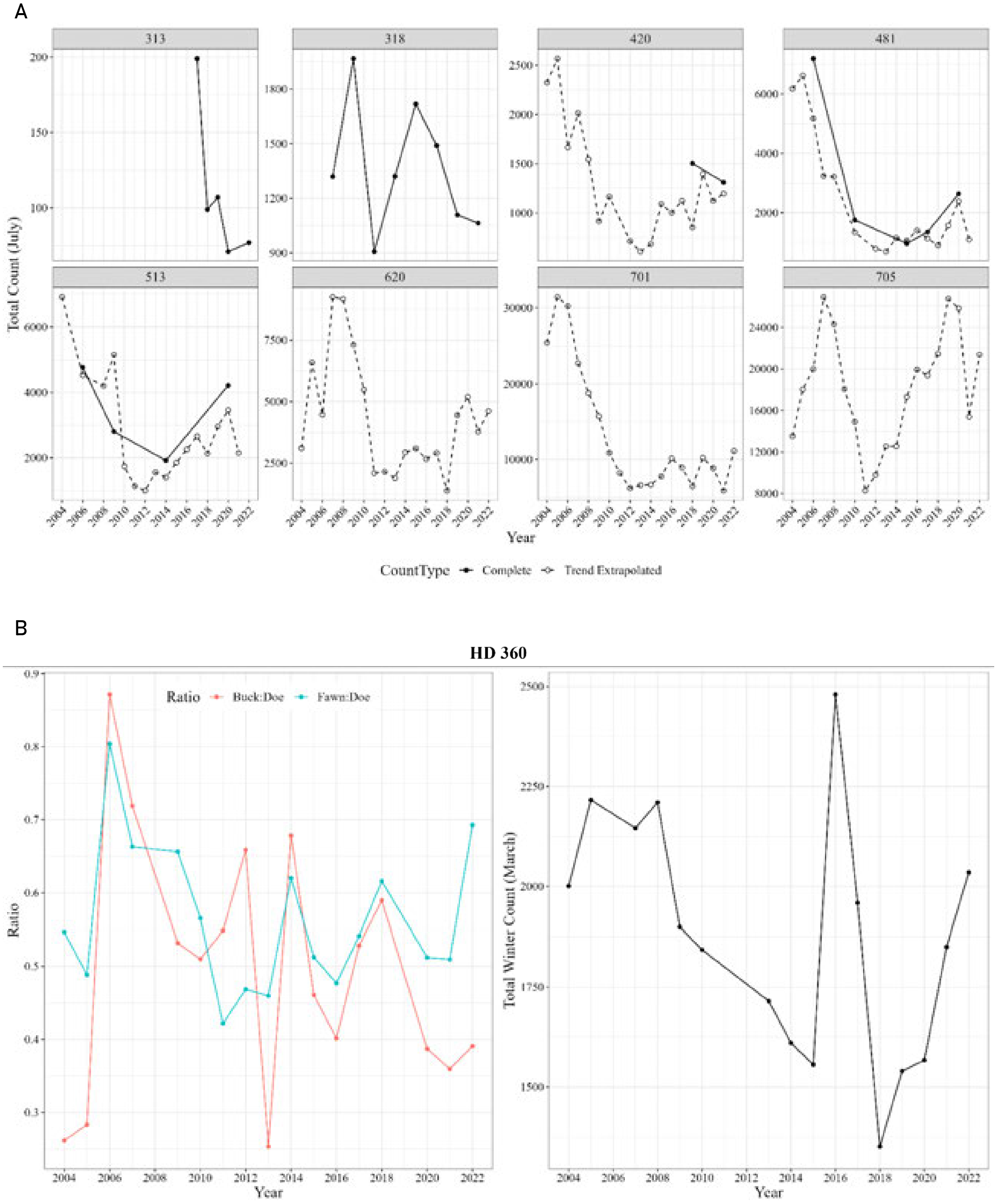


Figure 73. Pronghorn count data from 2004–2022, collected across 9 hunting districts (HDs) in Montana. Panel A includes hunting districts that used summer stage-structured complete counts (solid dots) and/or trend extrapolated counts (open dots) to monitor populations. Panel B includes HD 360, which used summer age/sex ratios (red = buck:doe; blue = fawn:doe) and winter complete counts to monitor populations.

Table 10. Pronghorn count data from 2004–2022, collected across 9 hunting districts (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. Values included for TE survey types represent the trend extrapolated count that was later included in integrated population models (i.e., trend area counts extrapolated to the area of pronghorn habitat in the hunting district). 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
	2021	July	CC	--	51	10	34	7	0
	2022	July	CC	--	77	14	51	12	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
	2021	July	CC	--	942	160	513	391	12
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	--	--	--	--

HD	Year	Survey Month	Survey Type	Trend Areas	Total	Bucks	Does	Fawns	Unk
	2015	August	CC	--	1435	331	718	368	18
	2016	March	CC	--	2480	--	--	--	--
	2016	July	CC	--	1166	245	610	291	20
	2017	February	CC	--	1959	--	--	--	--
	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
	2021	March	CC	--	1850	--	--	--	--
	2021	July	CC	--	499	96	267	136	0
	2022	March	CC	--	2035	--	--	--	--
	2022	July	CC	--	400	75	192	133	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
	2018	July	CC	--	1504	408	791	305	0
	2019	July	TE	Yellow Water Triangle	1398	326	715	356	0
	2020	July	TE	Yellow Water Triangle	1125	246	648	231	0
	2021	July	TE	Yellow Water Triangle	1196	299	695	203	0
	2021	July	CC	--	1312	301	720	291	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

HD	Year	Survey Month	Survey Type	Trend Areas	Total	Bucks	Does	Fawns	Unk
	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
	2019	July	TE	Warhorse	1571	310	689	572	0
	2020	July	TE	Warhorse	2388	395	1272	721	0
	2020	July	CC	--	1571	310	689	572	0
	2021	July	TE	Warhorse	1101	401	566	134	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
	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
	2021	July	TE	North, South	2149	585	1225	339	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
	2020	July/August	TE	Count Unit 3, Count Unit 8	5195	1088	2788	1319	0
	2021	July/August	TE	Count Unit 3, Count Unit 8	3779	858	2266	655	0

HD	Year	Survey Month	Survey Type	Trend Areas	Total	Bucks	Does	Fawns	Unk
	2022	July/August	TE	Count Unit 3, Count Unit 8	4619	982	3009	628	0
701	2004	July	TE	Froze To Death, Plenty Creek, Sagehen	25479	6900	11157	7422	0
	2005	July	TE	Froze To Death, Plenty Creek, Sagehen	31445	7042	13895	10508	0
	2006	July	TE	Froze To Death, Plenty Creek, Sagehen	30226	6346	13024	10856	0
	2007	July	TE	Froze To Death, Plenty Creek, Sagehen	22757	6014	10271	6473	0
	2008	July	TE	Froze To Death, Plenty Creek, Sagehen	18785	4431	9551	4803	0
	2009	July	TE	Froze To Death, Plenty Creek, Sagehen	15723	3426	7351	4945	0
	2010	July	TE	Froze To Death, Plenty Creek, Sagehen	10872	2698	5895	2279	0
	2011	July, August, July	TE	Froze To Death, Plenty Creek, Sagehen	8198	2018	4534	1646	0
	2012	July, July, July	TE	Froze To Death, Plenty Creek, Sagehen	6196	1116	3347	1733	0
	2013	July, August, July	TE	Froze To Death, Plenty Creek, Sagehen	6575	1495	3861	1219	0
	2014	July, July, July	TE	Froze To Death, Plenty Creek, Sagehen	6639	950	2991	2698	0
	2015	August, August, July	TE	Froze To Death, Plenty Creek, Sagehen	7754	1836	3450	2469	0
	2016	August, July, July	TE	Froze To Death, Plenty Creek, Sagehen	10136	2255	4961	2920	0
	2017	July	TE	Froze To Death, Plenty Creek, Sagehen	8902	2073	3814	3015	0
	2018	July	TE	Froze To Death, Plenty Creek, Sagehen	6433	1796	3031	1606	0
	2019	July	TE	Froze To Death, Plenty Creek, Sagehen	10199	2121	4930	3149	0
	2020	July	TE	Froze To Death, Plenty Creek, Sagehen	8823	1954	4977	1891	0
	2021	July	TE	Froze To Death, Plenty Creek, Sagehen	5847	1416	2983	1448	0
	2022	July	TE	Froze To Death, Plenty Creek, Sagehen	11117	2318	6156	2643	0
705	2004	July	TE	Medicine Rocks, South Deadboy, Thompson Creek	13532	3441	5361	4730	0
	2005	July	TE	Medicine Rocks, South Deadboy, Thompson Creek	18042	5662	6814	5566	0
	2006	July	TE	Medicine Rocks, South Deadboy, Thompson Creek	19989	5045	8185	6759	0

HD	Year	Survey Month	Survey Type	Trend Areas	Total	Bucks	Does	Fawns	Unk
	2007	July	TE	Medicine Rocks, South Deadboy, Thompson Creek	26858	7924	10337	8596	0
	2008	July	TE	Medicine Rocks, South Deadboy, Thompson Creek	24308	7732	9707	6869	0
	2009	July	TE	Medicine Rocks, South Deadboy, Thompson Creek	18138	5278	7006	5786	0
	2010	July	TE	Medicine Rocks, South Deadboy, Thompson Creek	14917	3619	5950	5347	0
	2011	August, July, July	TE	Medicine Rocks, South Deadboy, Thompson Creek	8281	2029	3647	2605	0
	2012	July	TE	Medicine Rocks, South Deadboy, Thompson Creek	9816	2276	4058	3482	0
	2013	July, August, July	TE	Medicine Rocks, South Deadboy, Thompson Creek	12545	3496	5224	3825	0
	2014	August, July, July	TE	Medicine Rocks, South Deadboy, Thompson Creek	12558	3016	5100	4442	0
	2015	August, August, July	TE	Medicine Rocks, South Deadboy, Thompson Creek	17302	4332	7047	5923	0
	2016	July	TE	Medicine Rocks, South Deadboy, Thompson Creek	19934	6142	7993	5799	0
	2017	July	TE	Medicine Rocks, South Deadboy, Thompson Creek	19427	5388	7376	6622	0
	2018	July	TE	Medicine Rocks, South Deadboy, Thompson Creek	21456	5100	8363	7993	0
	2019	July	TE	Medicine Rocks, South Deadboy, Thompson Creek	26790	6293	10804	9583	110
	2020	July	TE	Medicine Rocks, South Deadboy, Thompson Creek	25761	6060	10543	9158	0
	2021	July	TE	Medicine Rocks, South Deadboy, Thompson Creek	15588	4730	6800	3866	192
	2022	July	TE	Medicine Rocks, South Deadboy, Thompson Creek	21429	4428	9268	7678	55

For hunting districts with stage-structured complete summer counts (excluding HD 360), we assumed counts represented a minimum of the true population size. Thus, we modeled stage-structured counts as binomial random variables with the number of "trials" equal to the latent true population size in summer (N), the probability of "success" equal to the proportion of individuals in the population that were counted each year (p_t), and the variance equal to $N * p(1-p)$:

$$\text{Complete Count}_t^{age/sex} \sim \text{Binomial}(N_t^{Summer}, p_t) \tag{Eq. 1}$$

Raw trend counts represented a proportion of the entire population. Thus, for hunting districts with trend extrapolated counts (HDs 420, 481, 513, 620, 701, 705), we modeled stage-structured raw trend counts as binomial random variables with the number of "trials" equal to the latent true population size in summer (N) and the probability of "success" equal to the proportion of pronghorn habitat within the hunting district that the trend area covered (p_{area}). Because the representativeness of the trend area may change from year to year (e.g., more pronghorn in the trend area than what is representative of the entire hunting district), we allowed p_{area} to vary by year (t):

$$\text{Trend Count}_t^{Age/sex} \sim \text{Binomial}\left(N_t^{Age/sex,\ \ Summer}, p_{area_t}\right) \tag{Eq. 2}$$

For hunting districts with complete, total winter counts (HD 360), we modeled counts as Normal random variables, which allowed counts to be above or below the true population size, given the considerable intra-annual movement of the population. In this model, the mean was the latent true population size in winter and the variance was estimated by the model.

$$\text{Complete Count}_t^{Total} \sim \text{Normal}\left(N_t^{Winter}, \sigma\right) \tag{Eq. 3}$$

For hunting districts that used summer age/sex ratios for population monitoring (HD 360), we modeled fawn counts as Poisson random variables with the mean rate parameter equal to the latent true age ratio (fawn:doe) multiplied by the adult female count:

$$\text{Count}_t^{Fawn} \sim \text{Poisson}\left(\text{Count}_t^{Adult\ female} * (N_t^{Fawn}/N_t^{Adult\ female})\right) \tag{Eq. 4}$$

We did not include male:female ratios in HD 360 models because it introduced additional uncertainty, which resulted in poor model fit.

Because counts occurred in both the summer and winter seasons, depending on the hunting district, we adjusted model-estimated latent true population size to match timing of observations. We subtracted harvest from model anniversary (01 Oct) population estimates, then multiplied by annual natural survival estimates, exponentiated by either 6/12 (for winter counts) or 9/12 (for summer counts).

Harvest data

Pronghorn fall harvest data are collected each year within three age/sex classes (juvenile, adult female, adult male; Figure 74; Table 11) via hunter call surveys (Lukacs et al. 2011). For each hunting district, we modeled harvest observations as Binomial random variables with the number of "trials" equal to the latent true population size of the age/sex class immediately before harvest (N) and the probability of "success" equal to the harvest rate of the age/sex class (h):

$$\text{Harvest}_t^{Age/sex} \sim \text{Binomial}\left(N_t^{Age/sex}, h_t^{Age/sex}\right) \tag{Eq. 5}$$

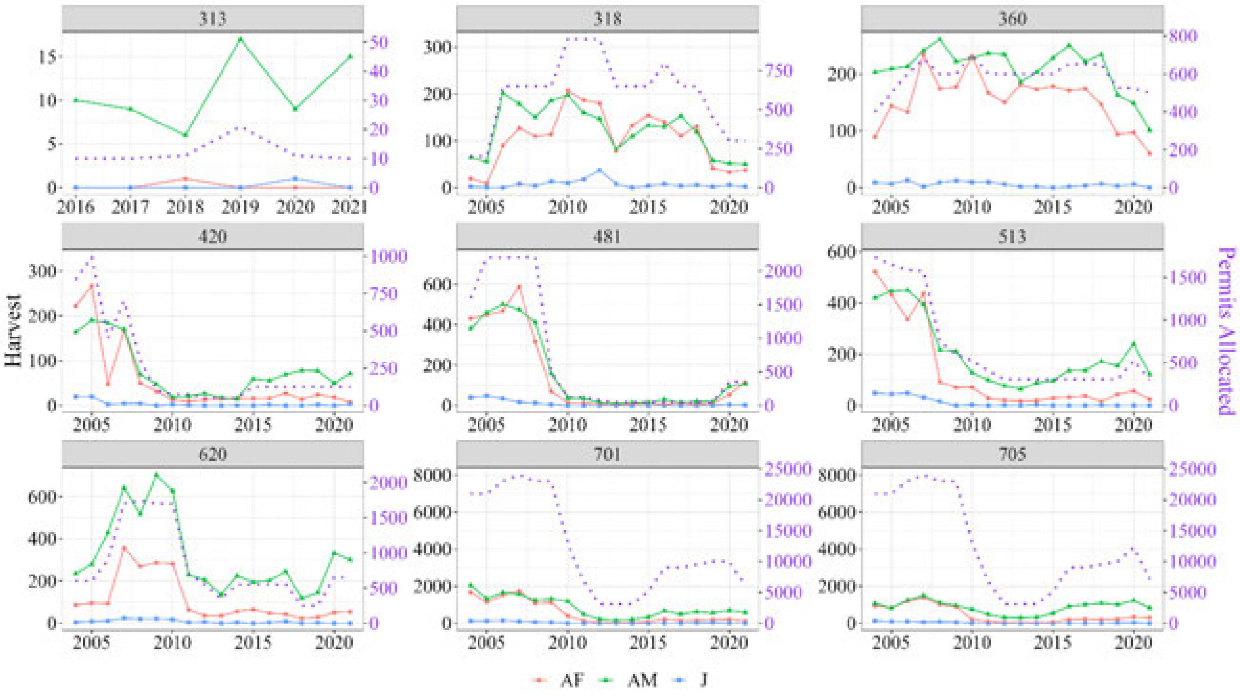


Figure 74. Pronghorn harvest estimates from 2004–2021, collected across 9 hunting districts (HDs) in Montana. Red circles, green triangles, and blue squares represent adult female, adult male, and juvenile harvest, respectively. Purple dots represent the total number of permits issued; displayed on the secondary axis.

Table 11. Pronghorn harvest estimates and hunting effort (number of permits issued) for adult males ("Bucks"), adult females ("Does"), and juveniles, each year from 2004 – 2021 across nine hunting districts (HD) in Montana.

		Harvest				Effort		
HD	Year	Total	Bucks	Does	Juveniles	Bucks	Does	Juveniles
313	2016	10	10	0	0	10	10	10
	2017	9	9	0	0	10	10	10
	2018	7	6	1	0	11	11	11
	2019	17	17	0	0	21	21	21
	2020	10	9	0	1	11	11	11
	2021	15.1	15.1	0	0	10	10	10
318	2004	84	64	19	2	201	201	201
	2005	67	56	9	1	200	200	200
	2006	295	202	90	0	451	651	651
	2007	314	179	127	8	450	650	650
	2008	264	150	110	4	451	651	651
	2009	313	186	114	13	450	650	650
	2010	415	198	207	10	451	951	951
	2011	366	160	187	18	450	950	950
	2012	364	147	180	37	450	950	950
	2013	167	81	78	8	350	650	650
	2014	243	110	133	0	350	650	650
	2015	291	133	154	4	350	650	650
	2016	278	130	140	8	425	800	800
	2017	267	153	111	4	351	651	651
	2018	256	119	131	6	350	650	650
	2019	101	58	41	2	250	450	450
	2020	91	52	33	6	175	300	300
	2021	88.3	49.5	36.6	2.1	175	300	300

		Harvest				Effort		
HD	Year	Total	Bucks	Does	Juveniles	Bucks	Does	Juveniles
360	2004	305	203	89	9	400	400	400
	2005	360	209	144	7	400	500	500
	2006	359	213	133	13	499	599	599
	2007	476	241	234	2	501	679	679
	2008	444	261	174	9	500	600	600
	2009	412	222	177	12	500	600	600
	2010	469	228	231	10	501	701	701
	2011	412	236	167	10	502	602	602
	2012	390	234	150	6	500	600	600
	2013	368	186	181	2	500	601	601
	2014	379	203	173	2	500	600	600
	2015	406	228	178	0	501	601	601
	2016	424	250	171	2	501	652	652
	2017	399	222	174	4	500	650	650
	2018	387	234	146	7	500	650	650
	2019	259	163	94	3	500	526	526
	2020	251	148	97	6	500	525	525
	2021	161.2	101.3	59.9	0	500	500	500
420	2004	408	164	222	20	347	843	843
	2005	476	190	267	20	400	995	995
	2006	234	184	47	3	400	450	450
	2007	343	170	168	5	350	700	700
	2008	124	69	50	5	200	302	302
	2009	79	48	31	0	50	100	100
	2010	34	18	13	3	50	75	75
	2011	32	21	10	1	49	74	74
	2012	39	26	13	0	25	50	50
	2013	32	17	15	0	25	50	50
	2014	31	15	15	1	25	50	50
	2015	74	59	16	0	100	125	125
	2016	74	56	16	2	100	125	125
	2017	96	69	27	0	100	125	125
	2018	92	78	14	0	100	125	125
	2019	102	77	24	2	101	126	126
	2020	68	50	18	0	100	125	125
	2021	82.8	71	8	3.8	100	125	125
481	2004	858	381	431	40	750	1597	1597
	2005	959	461	448	47	1198	2200	2200
	2006	1022	503	470	34	1199	2199	2199
	2007	1082	476	589	17	1200	2201	2201
	2008	741	412	315	13	1200	2207	2207
	2009	231	157	69	6	400	500	500
	2010	52	38	15	0	100	125	125
	2011	48	35	13	0	100	125	125
	2012	22	15	8	0	50	75	75
	2013	15	11	4	0	25	50	50
	2014	22	14	8	0	25	50	50
	2015	26	16	10	0	25	50	50
	2016	35	30	6	0	25	50	50
	2017	26	15	11	0	25	50	50
	2018	26	21	5	0	25	49	49
	2019	32	19	11	2	25	50	50
	2020	150	93	53	5	150	350	350

		Harvest				Effort		
HD	Year	Total	Bucks	Does	Juveniles	Bucks	Does	Juveniles
	2021	224.7	107.2	114.9	2.6	150	350	350
513	2004	992	420	522	48	1000	1739	1739
	2005	923	447	432	44	1001	1651	1651
	2006	848	450	336	48	1000	1583	1583
	2007	863	395	437	31	1000	1576	1576
	2008	325	217	92	16	750	750	750
	2009	281	211	70	0	601	601	601
	2010	199	127	70	3	500	525	525
	2011	127	99	28	0	401	406	406
	2012	100	77	21	2	300	305	305
	2013	83	64	18	0	300	305	305
	2014	112	88	20	4	300	305	305
	2015	126	97	29	0	300	305	305
	2016	168	136	32	0	300	305	305
	2017	174	136	37	0	300	305	305
	2018	192	173	16	2	300	305	305
	2019	197	154	43	0	300	305	305
	2020	298	240	56	1	500	525	525
	2021	145.1	121.4	23.7	0	300	305	305
620	2004	330	235	86	5	502	602	602
	2005	385	280	95	9	499	599	599
	2006	535	429	93	11	800	900	900
	2007	1021	641	357	24	1200	1700	1700
	2008	807	516	270	20	1200	1748	1748
	2009	1012	703	287	22	1201	1701	1701
	2010	927	627	282	18	1200	1700	1700
	2011	296	230	63	3	600	700	700
	2012	248	205	36	6	503	553	553
	2013	170	135	36	0	300	350	350
	2014	284	225	56	3	500	550	550
	2015	259	194	65	0	501	551	551
	2016	253	202	48	3	501	551	551
	2017	296	245	43	8	500	550	550
	2018	142	119	23	0	200	250	250
	2019	176	145	29	2	201	251	251
	2020	383	333	51	0	600	650	650
	2021	355.1	301.1	54.1	0	600	650	650
701	2004	3843	2044	1666	123	12997	20992	20992
	2005	2599	1332	1143	121	12987	20983	20983
	2006	3427	1665	1524	157	13009	23025	23025
	2007	3399	1564	1732	103	13011	24040	24040
	2008	2384	1244	1077	64	13008	23042	23042
	2009	2482	1318	1118	47	13011	23013	23013
	2010	1595	1189	398	8	11014	13015	13015
	2011	610	480	130	0	6504	6753	6753
	2012	267	231	36	0	3008	3108	3108
	2013	208	161	47	0	3011	3111	3111
	2014	251	212	39	0	3011	3111	3111
	2015	411	336	75	0	5016	5116	5116
	2016	883	663	218	3	7514	9014	9014
	2017	657	505	146	6	7513	9013	9013
	2018	785	613	155	18	8010	9510	9510
	2019	781	560	199	23	8512	10012	10012

		Harvest				Effort		
HD	Year	Total	Bucks	Does	Juveniles	Bucks	Does	Juveniles
	2020	917	692	212	13	8501	10001	10001
	2021	713.5	589.3	121.8	2.4	6000	6150	6150
705	2004	2175	1075	943	129	12997	20992	20992
	2005	1736	809	834	86	12987	20983	20983
	2006	2592	1252	1199	92	13009	23025	23025
	2007	2950	1496	1391	63	13011	24040	24040
	2008	2195	1115	1006	74	13008	23042	23042
	2009	1896	948	892	57	13011	23013	23013
	2010	965	749	206	10	11014	13015	13015
	2011	571	477	91	2	6504	6753	6753
	2012	361	315	46	0	3008	3108	3108
	2013	333	304	29	0	3011	3111	3111
	2014	362	324	29	9	3011	3111	3111
	2015	612	546	65	1	5016	5116	5116
	2016	1112	908	194	10	7514	9014	9014
	2017	1239	1008	229	2	7513	9013	9013
	2018	1293	1087	200	5	8010	9510	9510
	2019	1255	1009	227	19	8512	10012	10012
	2020	1596	1229	339	28	8501	12277	12277
	2021	1134.7	827.3	300.4	7.1	6000	7150	7150

Survival data

During 2021 and 2022, we estimated survival for collared adult female pronghorn within each pronghorn population (see *Survival monitoring & analysis* section). We related these survival estimates (ϕ, σ) to associated survival parameters within the IPM (*S*) in the year they were collected using a Normal distribution:

$$\phi_t \sim \mathrm{Normal}(S_t, \sigma) \qquad \text{Eq. 6}$$

Model fitting

We used a Bayesian framework to fit the IPM, given its hierarchical structure. We assigned prior distributions for each parameter that were informed by past literature. We estimated posterior distributions of parameters by running three Markov Chain Monte Carlo (MCMC) chains, each for 100,000 iterations, with a burn-in of 50,000, and thinning of 10. We identified whether models converged by ensuring $\hat{R}$ values were <1.1 and by visually inspecting posterior distributions for adequate mixing. We determined that covariates influenced vital rates if 95% credible intervals (between 2.5% and 97.5% quantiles) of posterior distributions of parameter estimates did not overlap zero.

Using the models described above, we estimated annual true population size for each sex/age class, as well as population growth rates, demographic rates, and correlations between demographic rates and population growth. We also estimated geometric mean lambda and mean vital rates from 2015 – 2021/22 to determine the status of each population since 2015.

Results

HD 313

IPM results in HD 313 suggested a decreasing population since 2016, with a mean geometric lambda of 0.887 (0.84 – 0.97; Figure 75; Table 12; Appendix B). Estimated average adult female survival was 0.74 (0.69 – 0.79), adult male survival was 0.37 (0.30 – 0.45), and 4-month recruitment was 0.52 (0.35 – 0.76; Figure 76; Table 12). Annual lambda was most correlated with 4-month recruitment, with some evidence for correlation with adult female survival as well (Figure 77). Precipitation had a strong association with adult survival (β = 1.58 [0.70 – 2.55]), but there were no other strong effects (Table 4; Figure 78).

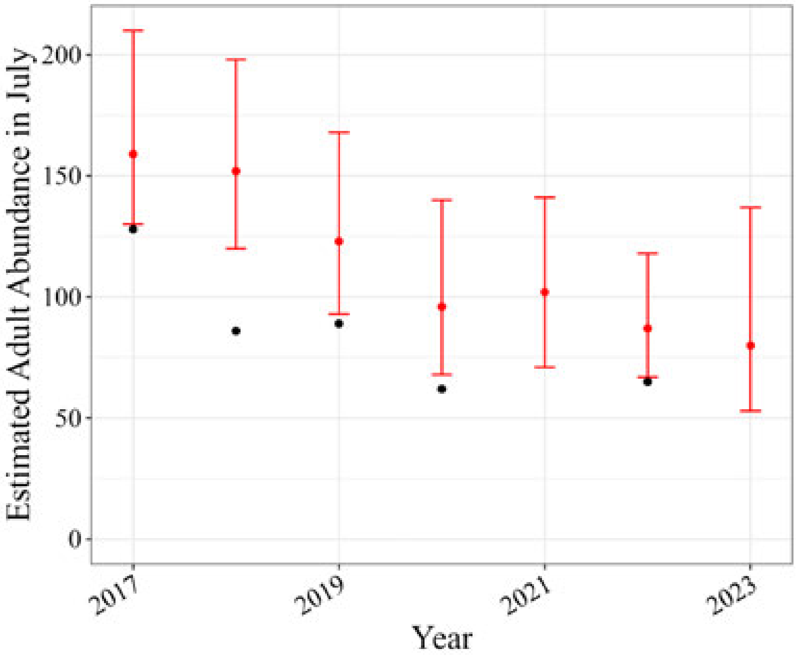
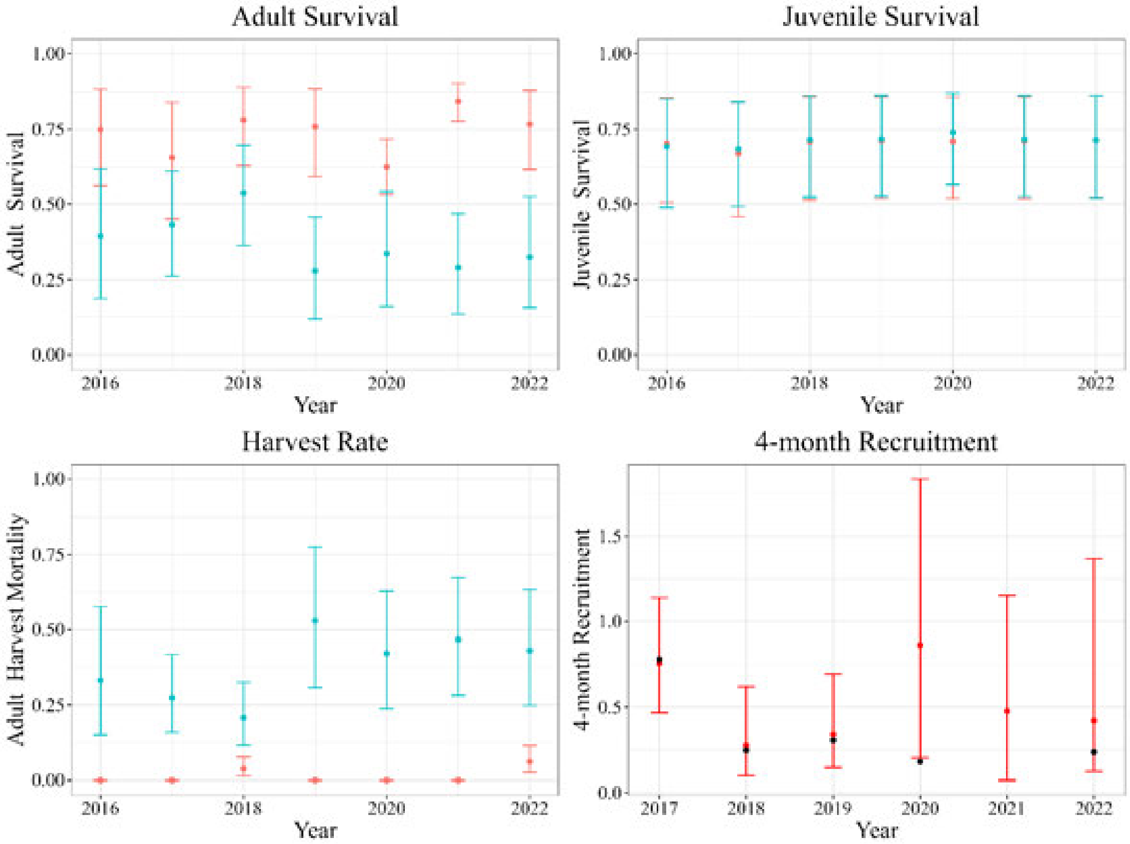


Figure 75. Pronghorn total July abundance in hunting district 313, estimated using an integrated population model. Red dots and error bars represent the mean abundance estimate with 95% credible intervals. Black dots represent the observed count, collected through aerial flights.


Adult Survival

Juvenile Survival

Harvest Rate

4-month Recruitment

Figure 76. Pronghorn vital rate estimates in hunting district 313, estimated using an integrated population model. Salmon dots in adult survival, juvenile survival, and harvest rate panels represent females, while blue dots represent males. Black dots in the 4-month recruitment panel represent observed fawn:doe ratios. All error bars are 95% credible intervals.

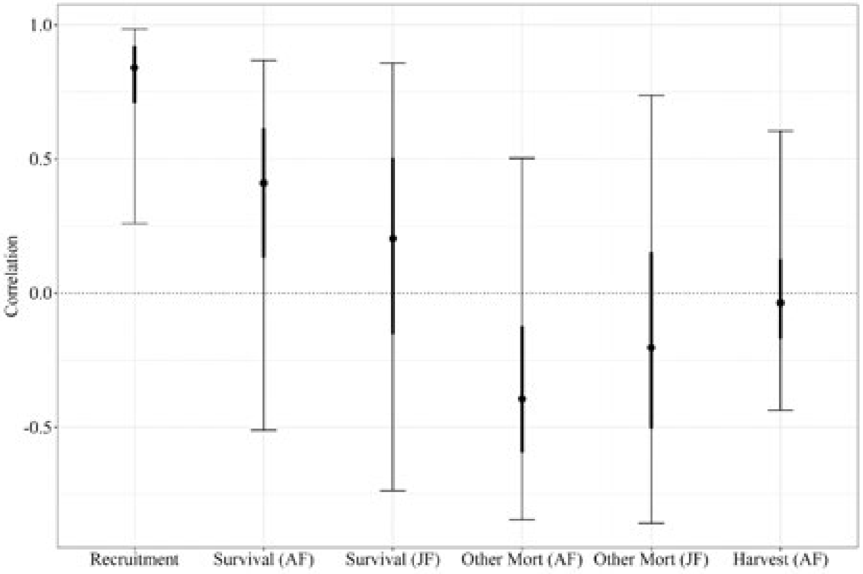


Figure 77. Correlation between annual pronghorn vital rate estimates (4-month recruitment, adult female [AF] survival, juvenile female [JF] survival, other mortality rates, and harvest rates) and population growth (lambda) in hunting district 313. Dots are mean correlation estimates, thin vertical bars are 95% credible intervals, and thick bars are 50% credible intervals. The dotted horizontal dotted line represents a correlation of 0 (i.e., where no correlation exists).

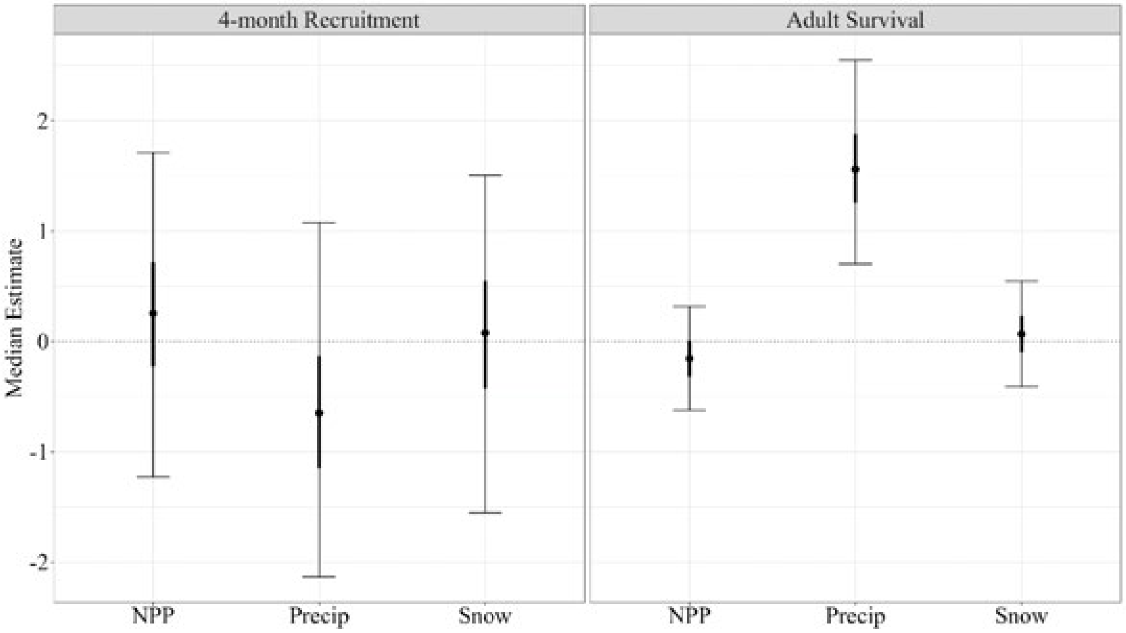


Figure 78. Beta estimates for covariates (net primary productivity [NPP], precipitation [Precip], and snow depth [Snow]) associated with pronghorn adult survival and 4-month recruitment in hunting district 313. Dots are median Beta estimates, thin vertical bars are 95% credible intervals, and thick bars are 50% credible intervals. The dotted horizontal dotted line represents a Beta estimate of 0 (i.e., where no effect exists).

HD 318

IPM results in HD 318 suggested a decreasing population since 2015, with a mean geometric lambda of 0.94 (0.91 – 0.98; Figure 79; Table 12; Appendix B). Estimated average adult female survival was 0.72 (0.69 – 0.79), adult male survival was 0.39 (0.33 – 0.46), and 4-month recruitment was 0.67 (0.57 – 0.79; Figure 80; Table 12). Annual lambda was most correlated with 4-month recruitment and adult female survival (Figure 81), but there were no strong associations of any covariates with annual vital rates (Table 4; Figure 82).

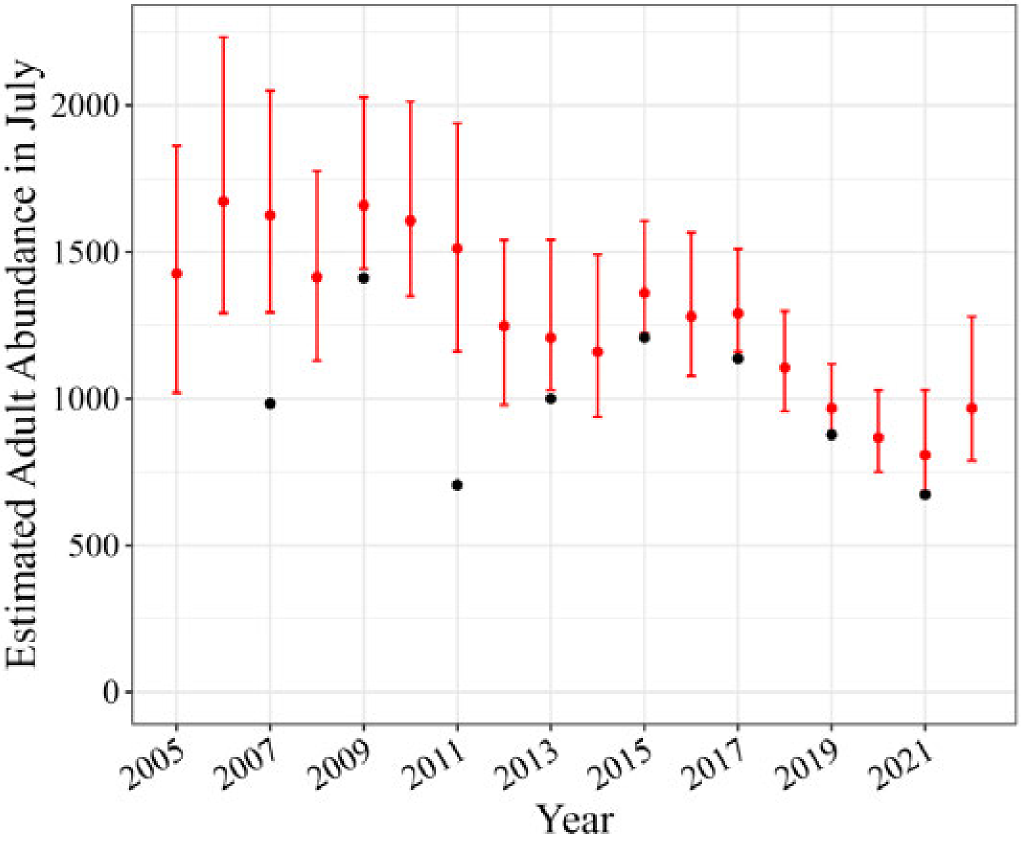


Figure 79. Pronghorn total July abundance in hunting district 318, estimated using an integrated population model. Red dots and error bars represent the mean abundance estimate with 95% credible intervals. Black dots represent the observed count, collected through aerial flights.

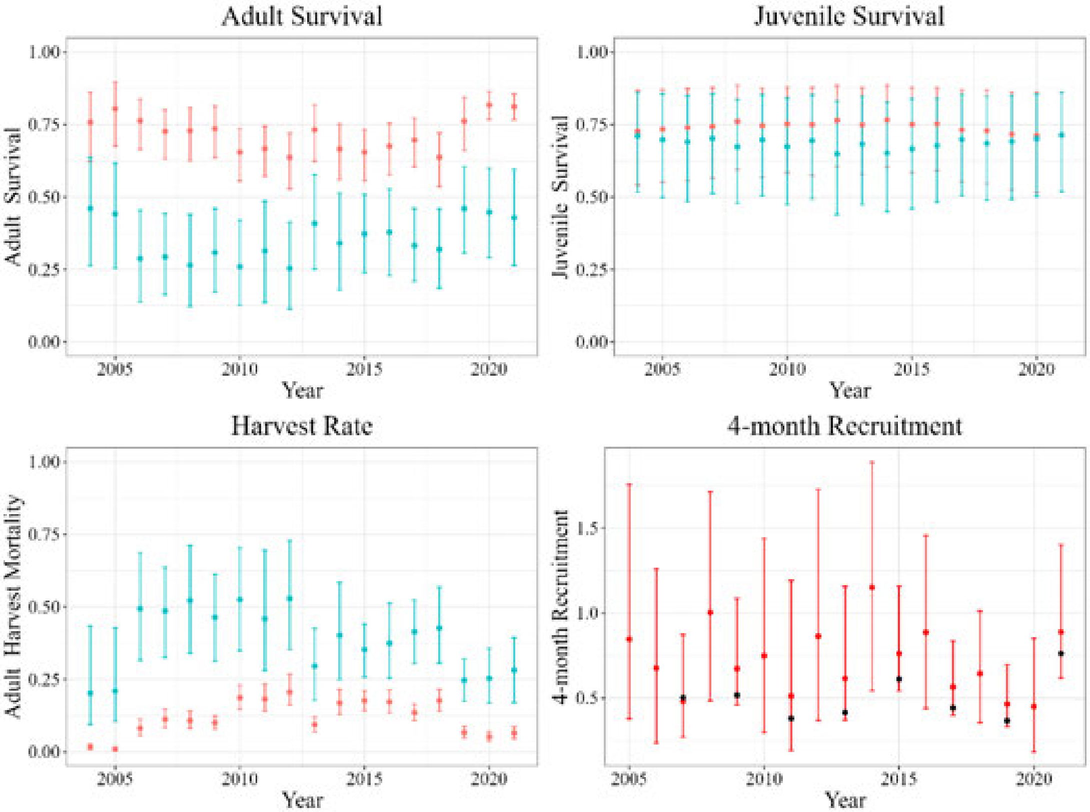


Figure 80. Pronghorn vital rate estimates in hunting district 318, estimated using an integrated population model. Salmon dots in adult survival, juvenile survival, and harvest rate panels represent females, while blue dots represent males. Black dots in the 4-month recruitment panel represent observed fawn:doe ratios. All error bars are 95% credible intervals.

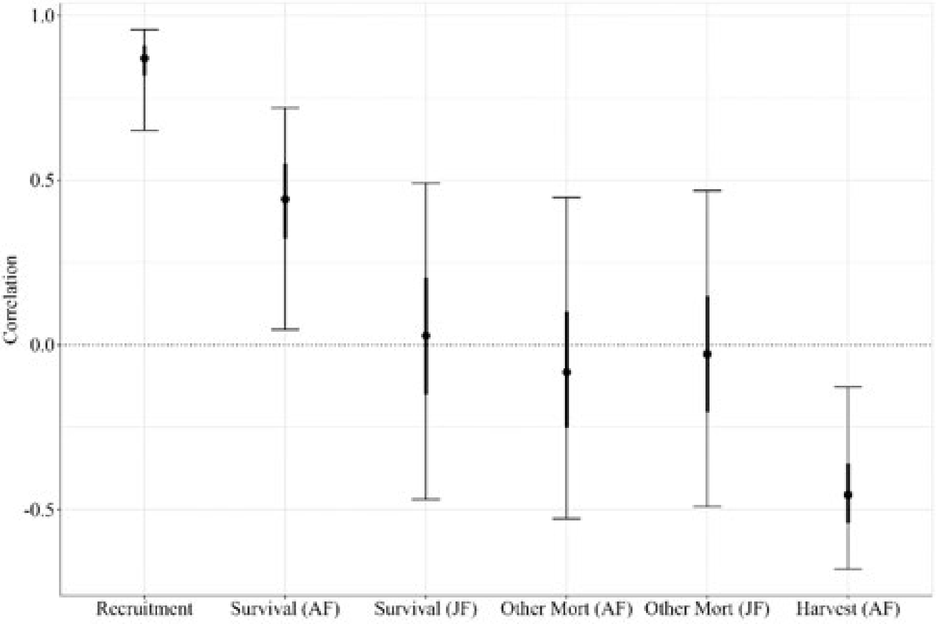


Figure 81. Correlation between annual pronghorn vital rate estimates (4-month recruitment, adult female [AF] survival, juvenile female [JF] survival, other mortality rates, and harvest rates) and population growth (lambda) in hunting district 318. Dots are mean correlation estimates, thin vertical bars are 95% credible intervals, and thick bars are 50% credible intervals. The dotted horizontal dotted line represents a correlation of 0 (i.e., where no correlation exists).

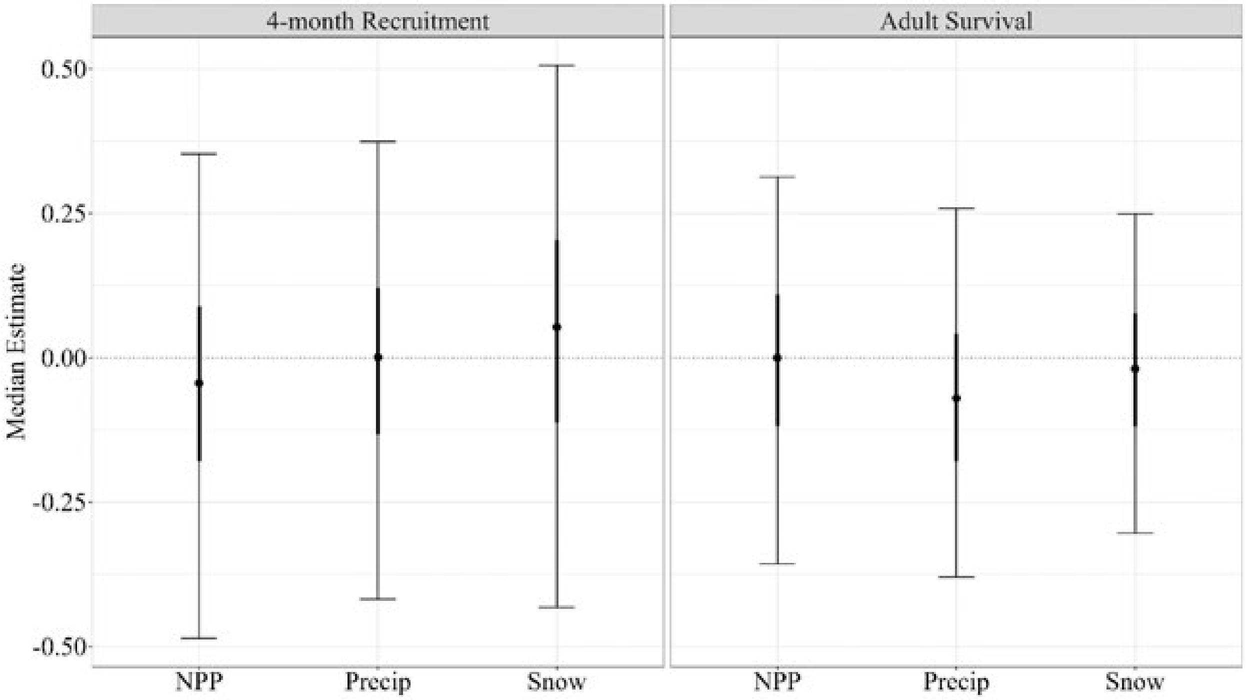


Figure 82. Beta estimates for covariates (net primary productivity [NPP], precipitation [Precip], and snow depth [Snow]) associated with pronghorn adult survival and 4-month recruitment in hunting district 318. Dots are median Beta estimates, thin vertical bars are 95% credible intervals, and thick bars are 50% credible intervals. The dotted horizontal dotted line represents a Beta estimate of 0 (i.e., where no effect exists).

HD 360

IPM results in HD 360 suggested a decreasing population since 2015, with a mean geometric lambda of 0.94 (0.91 – 0.97; Figure 83; Table 12; Appendix B). Estimated average adult female survival was 0.74 (0.70 – 0.77), adult male survival was 0.32 (0.26 – 0.40), and 4-month recruitment was 0.59 (0.52 – 0.68; Figure 84; Table 12). Annual lambda was most correlated with 4-month recruitment, with some evidence for correlation with adult female survival as well (Figure 85). There were no strong associations of any covariates with annual vital rates (Table 13; Figure 86).

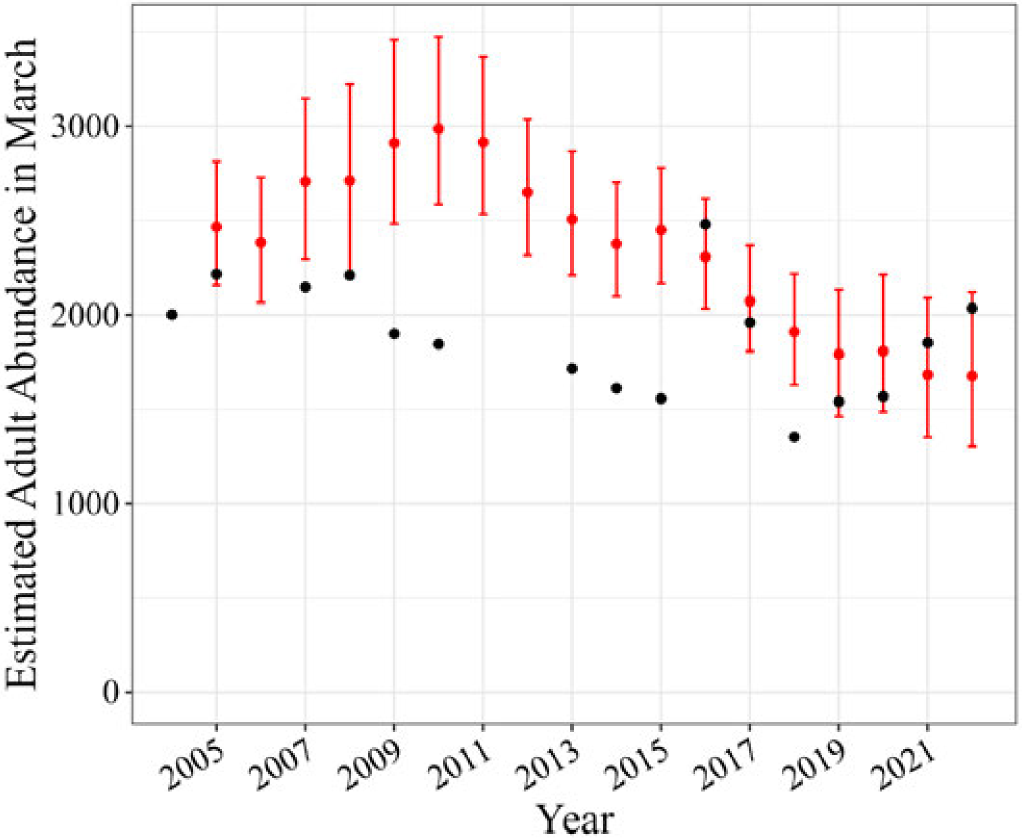


Figure 83. Pronghorn total July abundance in hunting district 360, estimated using an integrated population model. Red dots and error bars represent the mean abundance estimate with 95% credible intervals. Black dots represent the observed count, collected through aerial flights.

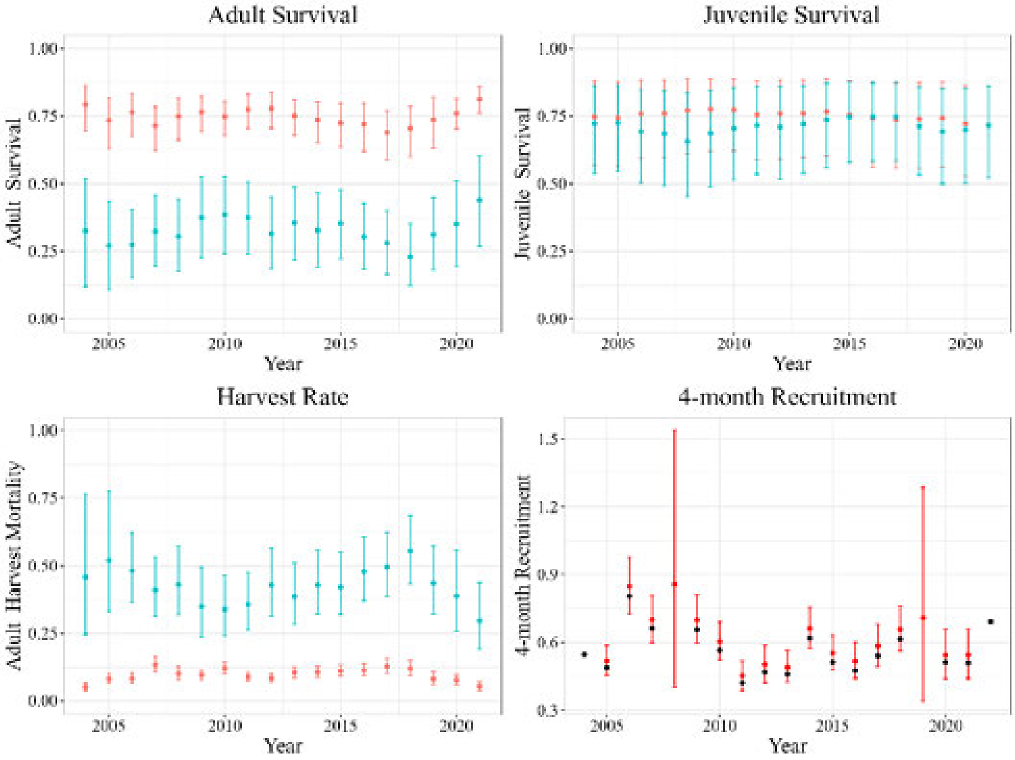


Figure 84. Pronghorn vital rate estimates in hunting district 360, estimated using an integrated population model. Salmon dots in adult survival, juvenile survival, and harvest rate panels represent females, while blue dots represent males. Black dots in the 4-month recruitment panel represent observed fawn:doe ratios. All error bars are 95% credible intervals.

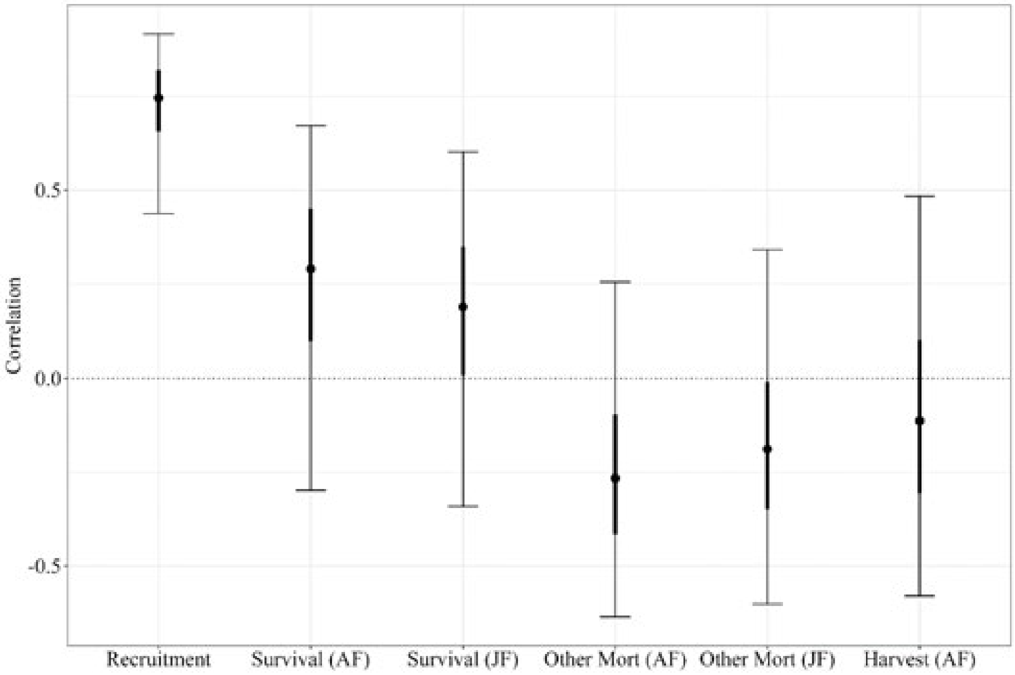


Figure 85. Correlation between annual pronghorn vital rate estimates (4-month recruitment, adult female [AF] survival, juvenile female [JF] survival, other mortality rates, and harvest rates) and population growth (lambda) in hunting district 360. Dots are mean correlation estimates, thin vertical bars are 95% credible intervals, and thick bars are 50% credible intervals. The dotted horizontal dotted line represents a correlation of 0 (i.e., where no correlation exists).

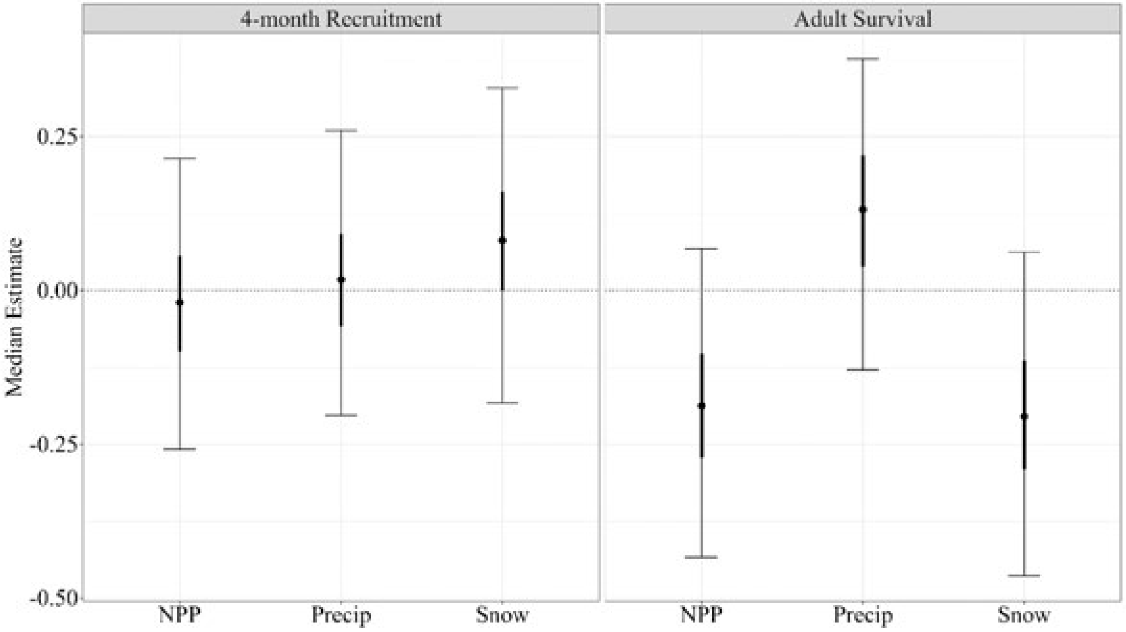


Figure 86. Beta estimates for covariates (net primary productivity [NPP], precipitation [Precip], and snow depth [Snow]) associated with pronghorn adult survival and 4-month recruitment in hunting district 360. Dots are median Beta estimates, thin vertical bars are 95% credible intervals, and thick bars are 50% credible intervals. The dotted horizontal dotted line represents a Beta estimate of 0 (i.e., where no effect exists).

HD 420

IPM results in HD 420 suggested a slightly increasing population since 2015, with a mean geometric lambda of 1.03 (1.02 – 1.05; Figure 87; Table 12; Appendix B). Estimated average adult female survival was 0.83 (0.81 – 0.85), adult male survival was 0.52 (0.47 – 0.57), and 4-month recruitment was 0.56 (0.50 – 0.63; Figure 88; Table 12). Annual lambda was most correlated with 4-month recruitment and adult female survival (Figure 89), but there were no strong associations of any covariates with annual vital rates (Table 13; Figure 90).

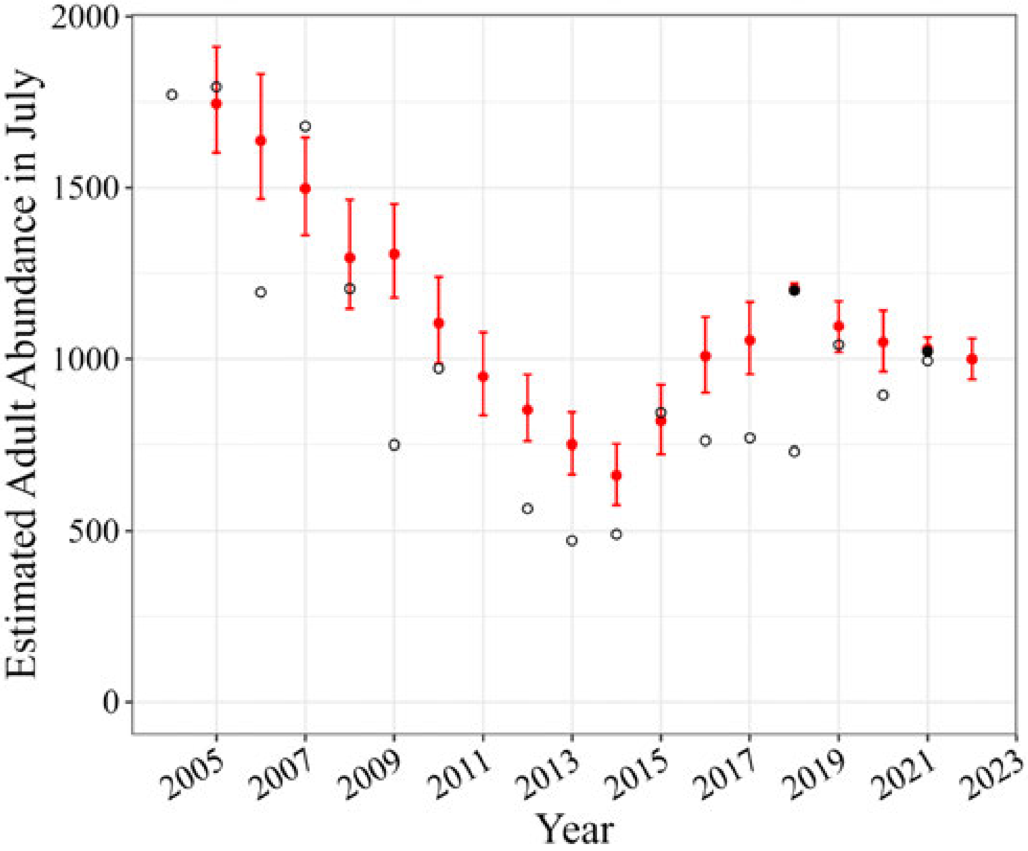


Figure 87. Pronghorn total July abundance in hunting district 420, estimated using an integrated population model. Red dots and error bars represent the mean abundance estimate with 95% credible intervals. Black dots represent the observed count, collected through aerial flights.

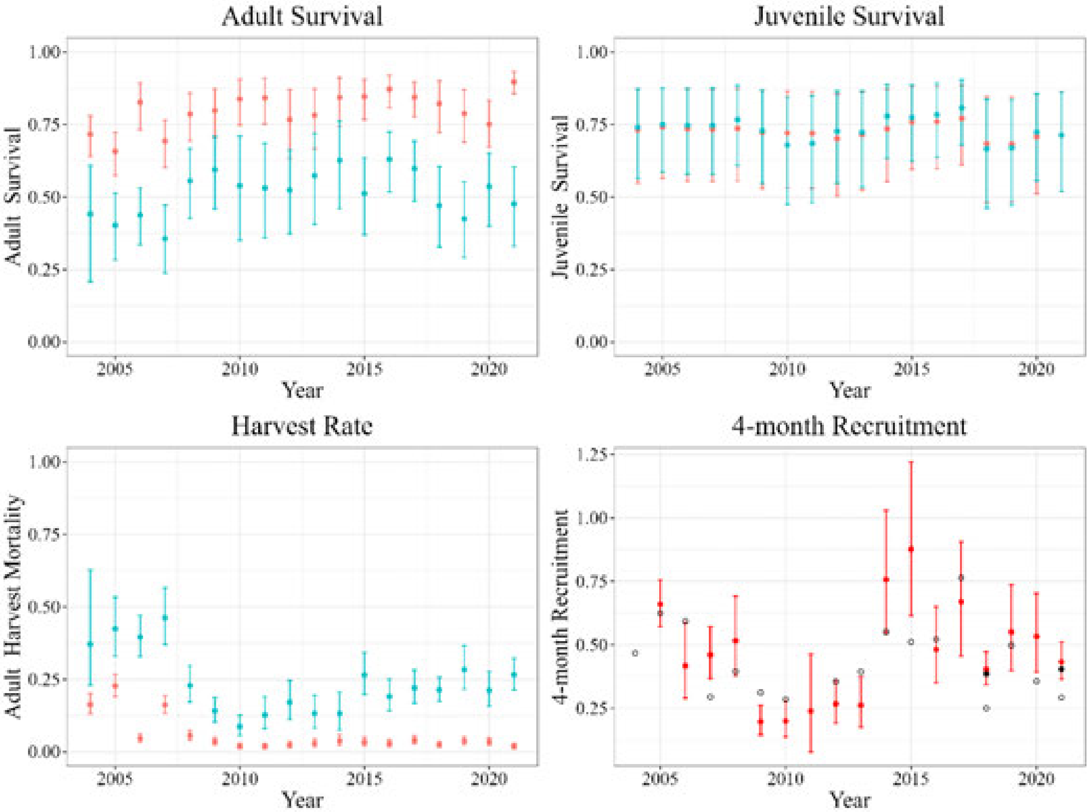


Figure 88. Pronghorn vital rate estimates in hunting district 420, estimated using an integrated population model. Salmon dots in adult survival, juvenile survival, and harvest rate panels represent females, while blue dots represent males. Black dots in the 4-month recruitment panel represent observed fawn:doe ratios. All error bars are 95% credible intervals.

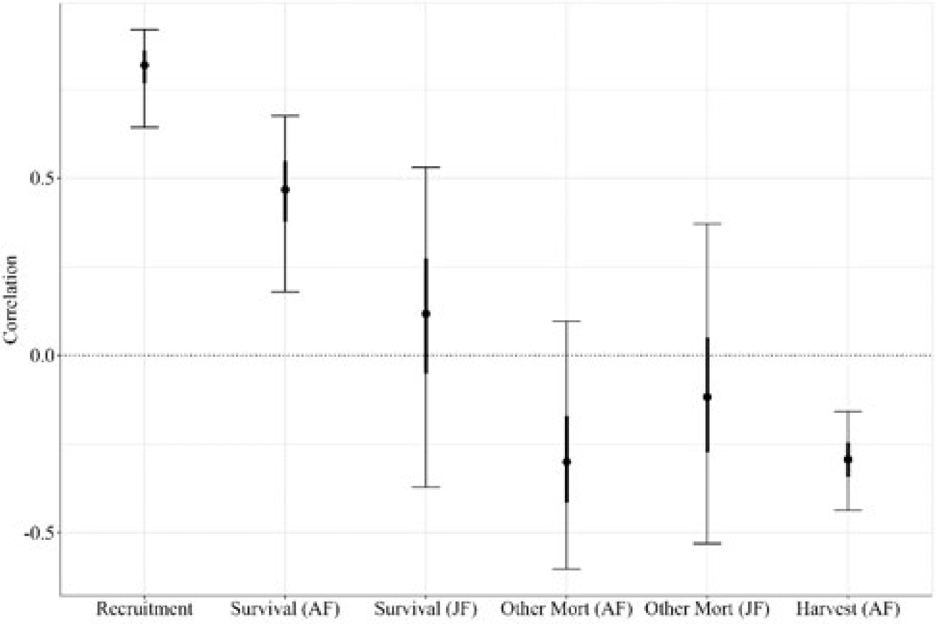


Figure 89. Correlation between annual pronghorn vital rate estimates (4-month recruitment, adult female [AF] survival, juvenile female [JF] survival, other mortality rates, and harvest rates) and population growth (lambda) in hunting district 420. Dots are mean correlation estimates, thin vertical bars are 95% credible intervals, and thick bars are 50% credible intervals. The dotted horizontal dotted line represents a correlation of 0 (i.e., where no correlation exists).

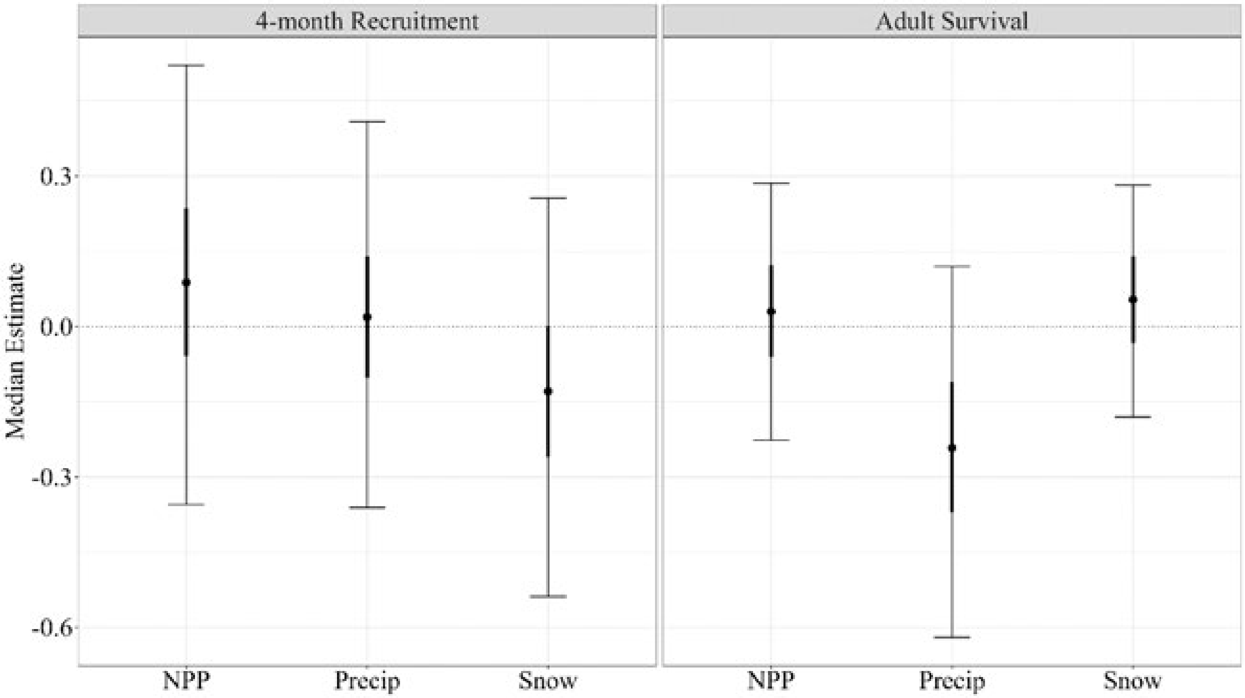


Figure 90. Beta estimates for covariates (net primary productivity [NPP], precipitation [Precip], and snow depth [Snow]) associated with pronghorn adult survival and 4-month recruitment in hunting district 420. Dots are median Beta estimates, thin vertical bars are 95% credible intervals, and thick bars are 50% credible intervals. The dotted horizontal dotted line represents a Beta estimate of 0 (i.e., where no effect exists).

HD 481

IPM results in HD 481 suggested an increasing population since 2015, with a mean geometric lambda of 1.12 (1.10 – 1.14; Figure 91; Table 12; Appendix B). Estimated average adult female survival was 0.86 (0.84 – 0.88), adult male survival was 0.59 (0.52 – 0.65), and 4-month recruitment was 0.69 (0.58 – 0.79; Figure 92; Table 12). Annual lambda was most correlated with 4-month recruitment and adult female survival (Figure 93). NPP (β = 0.33 [0.04 – 0.62]) and snow depth (β = 0.46 [0.13 – 0.78]) had a strong associations with adult survival, but there were no other strong effects (Table 13; Figure 94).

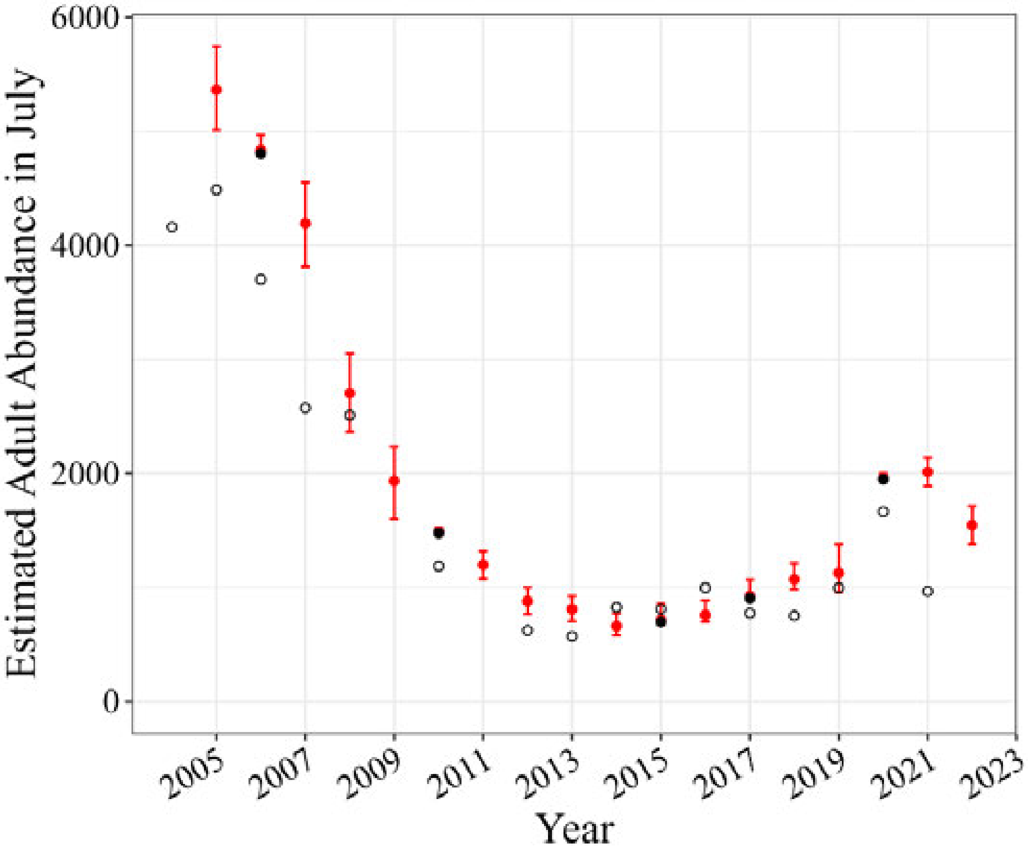


Figure 91. Pronghorn total July abundance in hunting district 481, estimated using an integrated population model. Red dots and error bars represent the mean abundance estimate with 95% credible intervals. Black dots represent the observed count, collected through aerial flights.

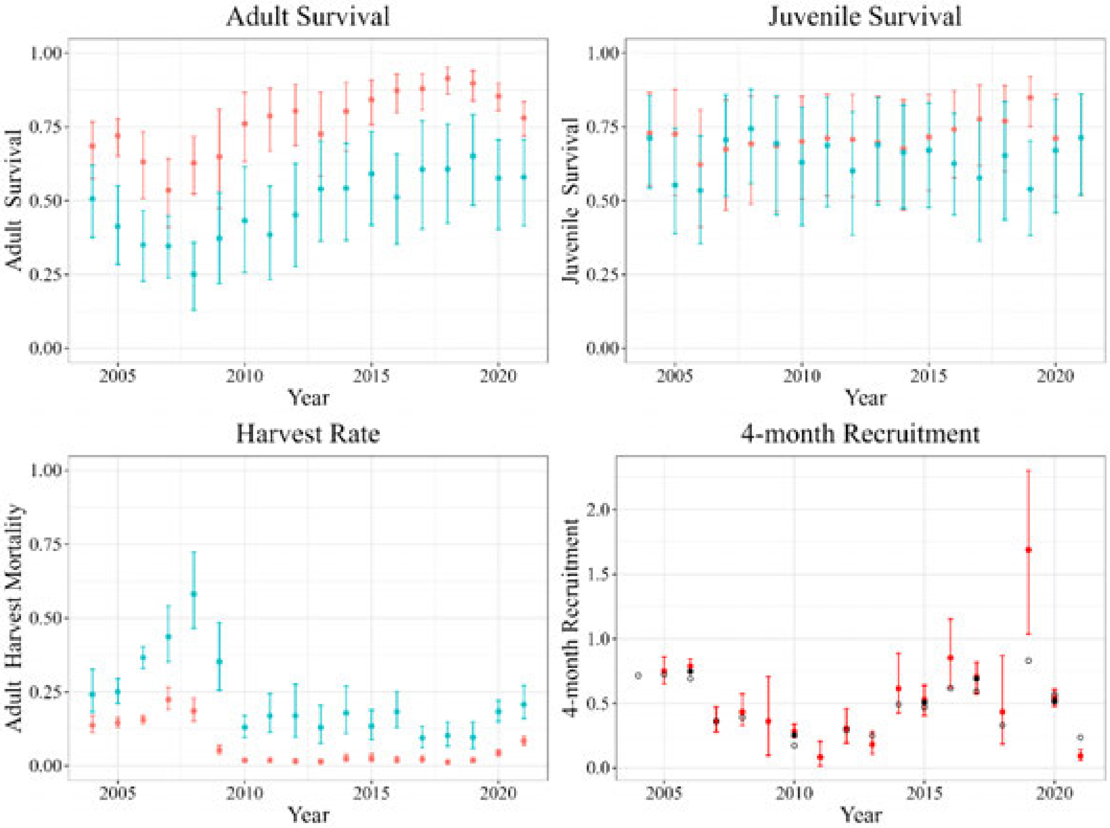


Figure 92. Pronghorn vital rate estimates in hunting district 481, estimated using an integrated population model. Salmon dots in adult survival, juvenile survival, and harvest rate panels represent females, while blue dots represent males. Black dots in the 4-month recruitment panel represent observed fawn:doe ratios. All error bars are 95% credible intervals.

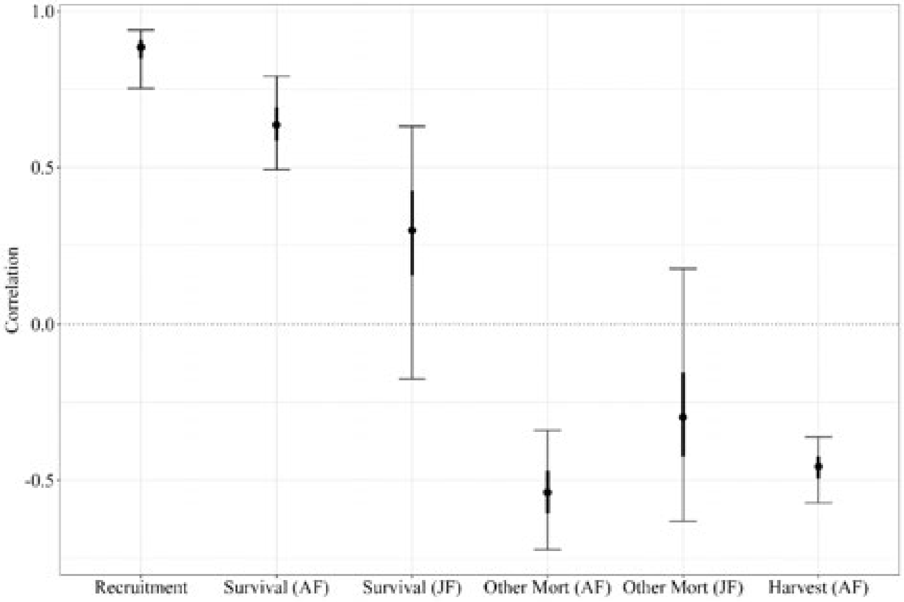


Figure 93. Correlation between annual pronghorn vital rate estimates (4-month recruitment, adult female [AF] survival, juvenile female [JF] survival, other mortality rates, and harvest rates) and population growth (lambda) in hunting district 481. Dots are mean correlation estimates, thin vertical bars are 95% credible intervals, and thick bars are 50% credible intervals. The dotted horizontal dotted line represents a correlation of 0 (i.e., where no correlation exists).

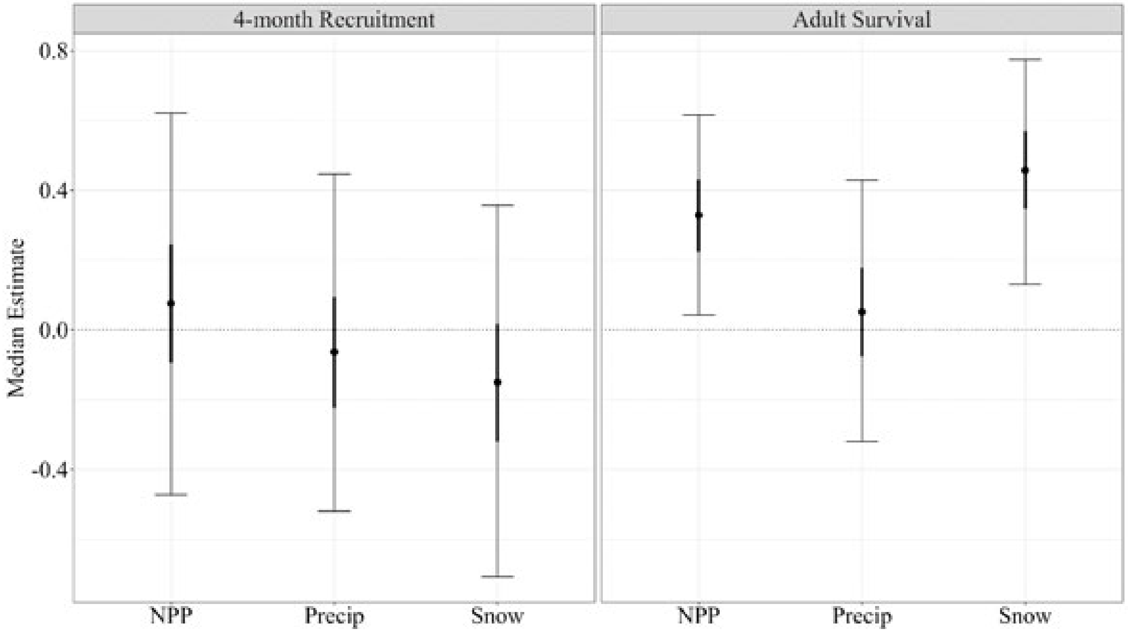


Figure 94. Beta estimates for covariates (net primary productivity [NPP], precipitation [Precip], and snow depth [Snow]) associated with pronghorn adult survival and 4-month recruitment in hunting district 481. Dots are median Beta estimates, thin vertical bars are 95% credible intervals, and thick bars are 50% credible intervals. The dotted horizontal dotted line represents a Beta estimate of 0 (i.e., where no effect exists).

HD 513

IPM results in HD 513 suggested a slightly increasing population since 2015, with a mean geometric lambda of 1.03 (1.00 – 1.07; Figure 95; Table 12; Appendix B). Estimated average adult female survival was 0.83 (0.79 – 0.87), adult male survival was 0.51 (0.40 – 0.63), and 4-month recruitment was 0.66 (0.55 – 0.82; Figure 96; Table 12). Annual lambda was most correlated with 4-month recruitment and adult female survival (Figure 97). NPP (β = 0.52 [-0.01 – 1.02]) and precipitation (β = -0.74 [-1.32 – -0.20]) had a fairly strong associations with adult survival, but there were no other strong effects (Table 13; Figure 98).

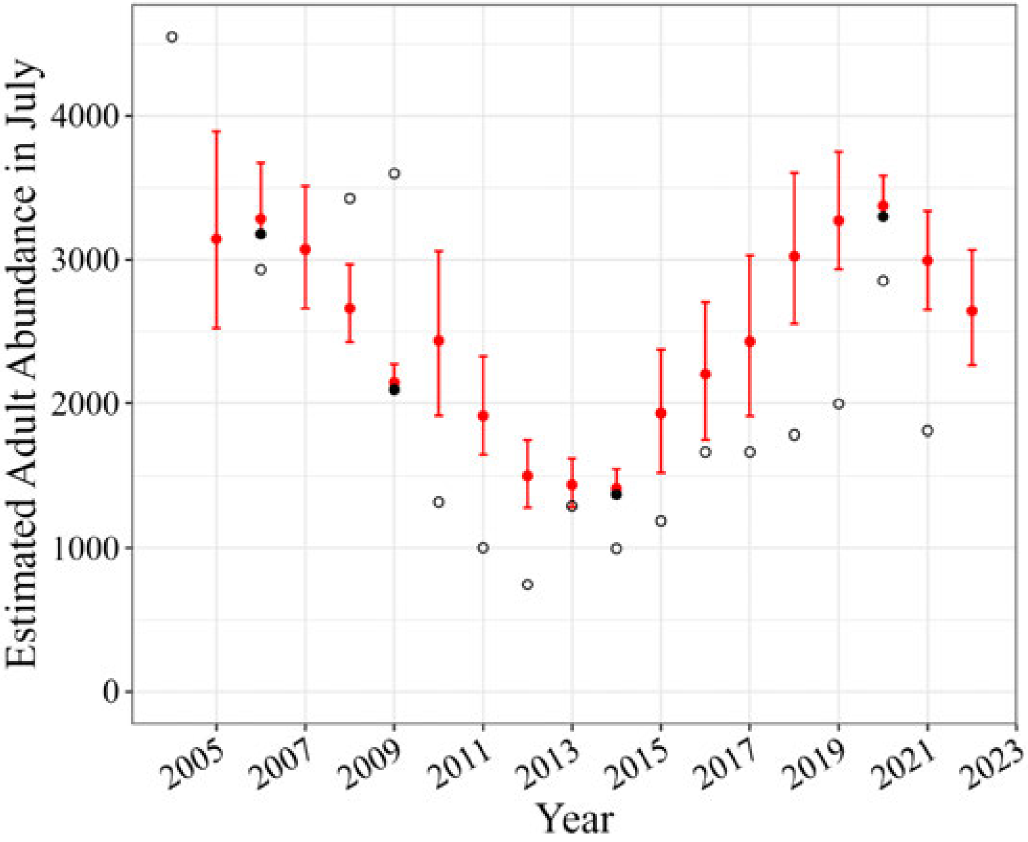


Figure 95. Pronghorn total July abundance in hunting district 513, estimated using an integrated population model. Red dots and error bars represent the mean abundance estimate with 95% credible intervals. Black dots represent the observed count, collected through aerial flights.

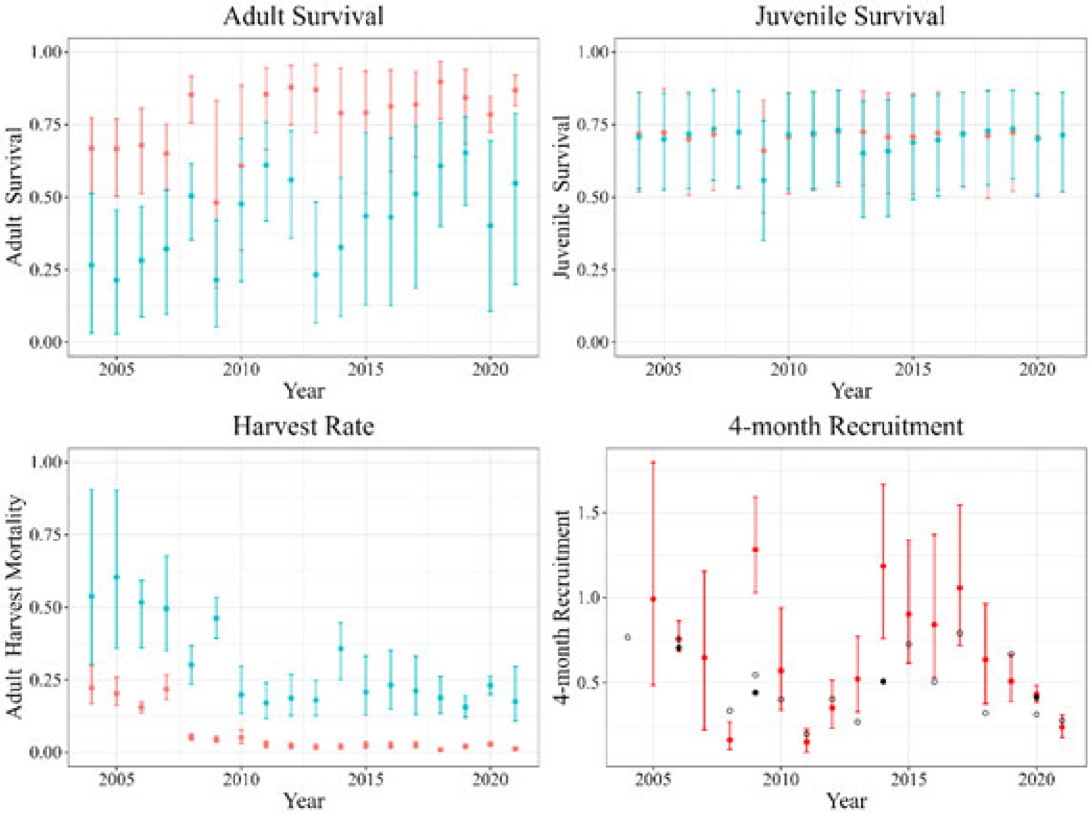


Figure 96. Pronghorn vital rate estimates in hunting district 513, estimated using an integrated population model. Salmon dots in adult survival, juvenile survival, and harvest rate panels represent females, while blue dots represent males. Black dots in the 4-month recruitment panel represent observed fawn:doe ratios. All error bars are 95% credible intervals.

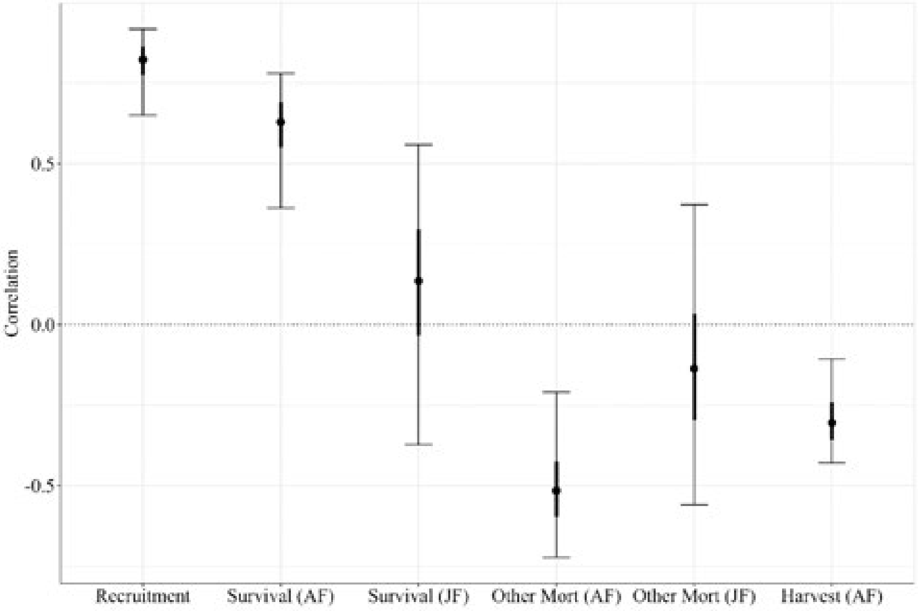


Figure 97. Correlation between annual pronghorn vital rate estimates (4-month recruitment, adult female [AF] survival, juvenile female [JF] survival, other mortality rates, and harvest rates) and population growth (lambda) in hunting district 513. Dots are mean correlation estimates, thin vertical bars are 95% credible intervals, and thick bars are 50% credible intervals. The dotted horizontal dotted line represents a correlation of 0 (i.e., where no correlation exists).

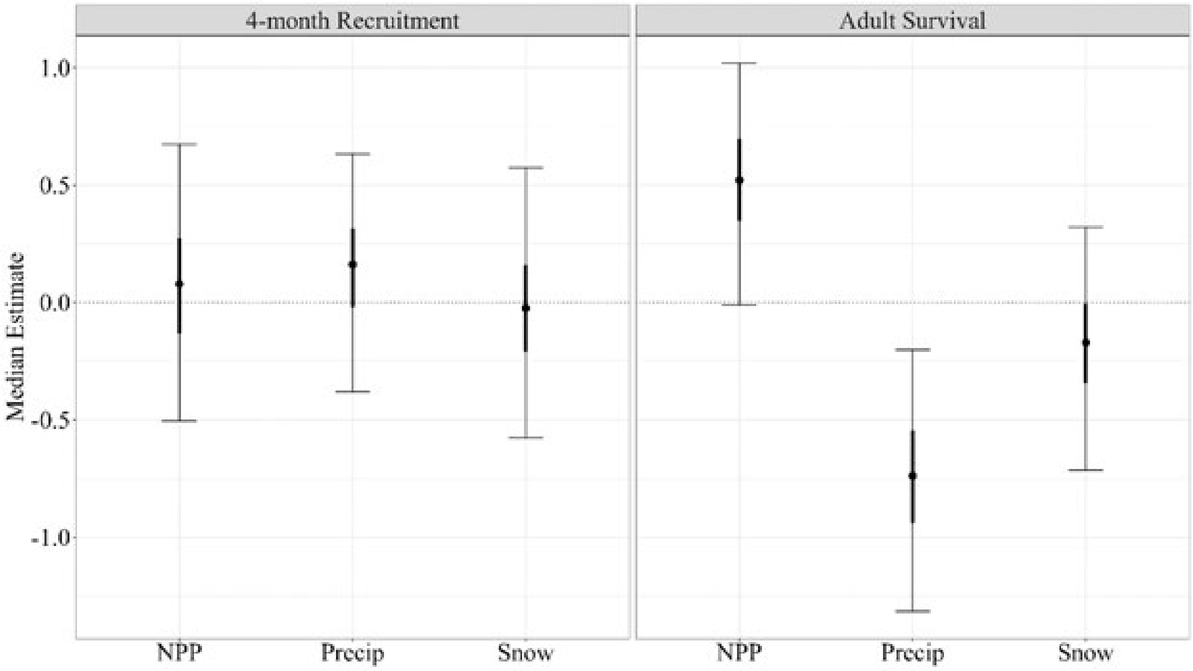


Figure 98. Beta estimates for covariates (net primary productivity [NPP], precipitation [Precip], and snow depth [Snow]) associated with pronghorn adult survival and 4-month recruitment in hunting district 513. Dots are median Beta estimates, thin vertical bars are 95% credible intervals, and thick bars are 50% credible intervals. The dotted horizontal dotted line represents a Beta estimate of 0 (i.e., where no effect exists).

HD 620

IPM results in HD 620 suggested an increasing population since 2015, with a mean geometric lambda of 1.04 (1.01 – 1.07; Figure 99; Table 12; Appendix B). Estimated average adult female survival was 0.78 (0.74 – 0.83), adult male survival was 0.32 (0.26 – 0.39), and 4-month recruitment was 0.82 (0.68 – 0.98; Figure 100; Table 12). Annual lambda was most correlated with 4-month recruitment and adult female survival (Figure 101). Snow depth (β = -0.34 [-0.63 – -0.06]) and precipitation (β = -0.36 [-0.71 – -0.03]) had a fairly strong associations with adult survival, and snow depth also had a moderate association with 4-month recruitment (β = -0.27 [-0.61 – 0.03]; Table 13; Figure 102).

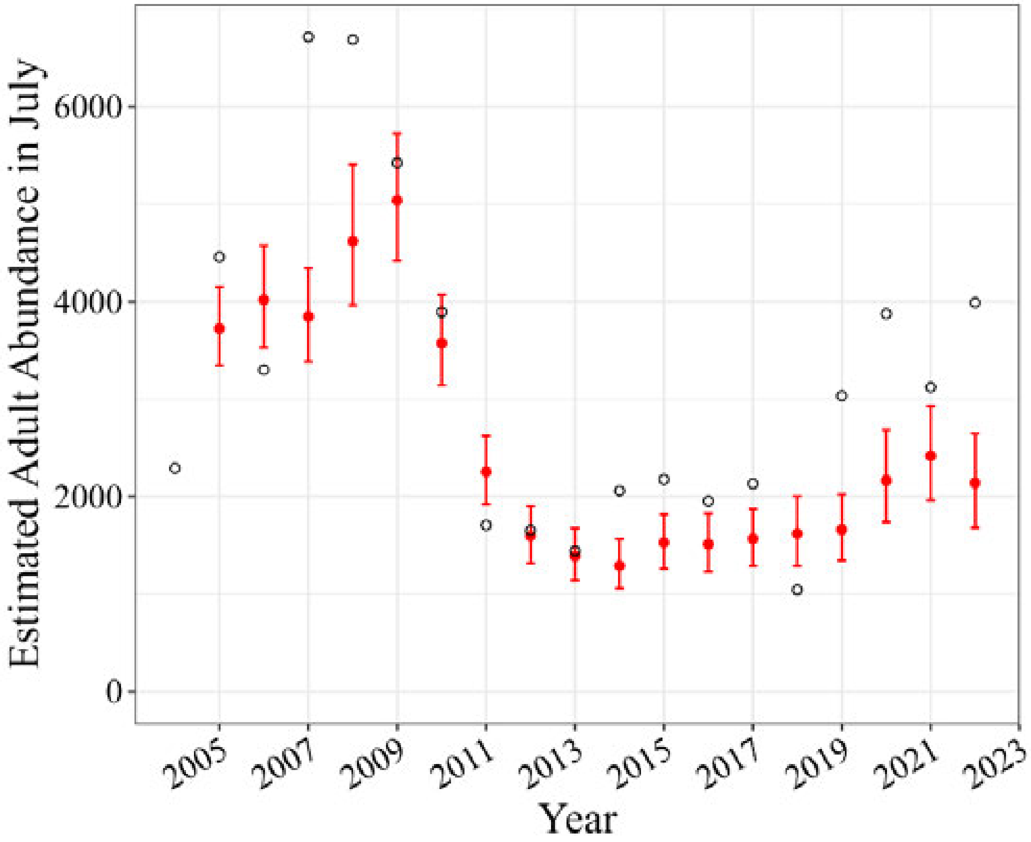


Figure 99. Pronghorn total July abundance in hunting district 620, estimated using an integrated population model. Red dots and error bars represent the mean abundance estimate with 95% credible intervals. Black dots represent the observed count, collected through aerial flights.

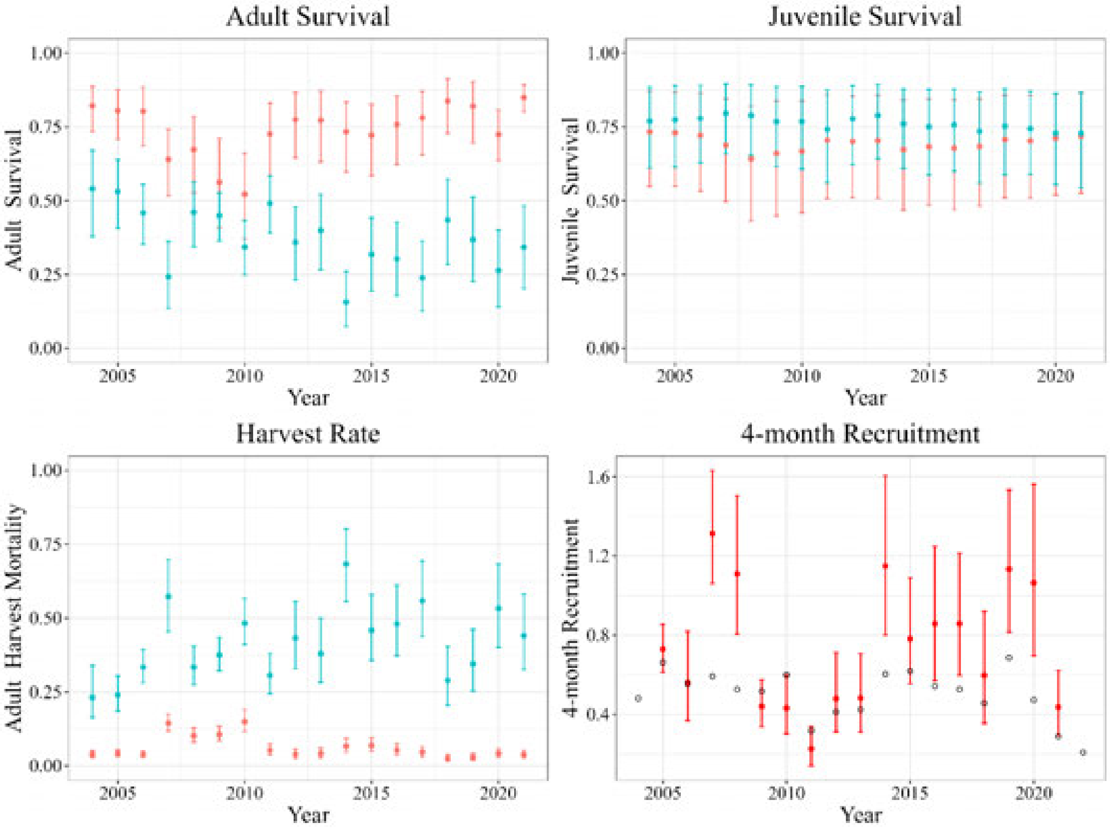


Figure 100. Pronghorn vital rate estimates in hunting district 620, estimated using an integrated population model. Salmon dots in adult survival, juvenile survival, and harvest rate panels represent females, while blue dots represent males. Black dots in the 4-month recruitment panel represent observed fawn:doe ratios. All error bars are 95% credible intervals.

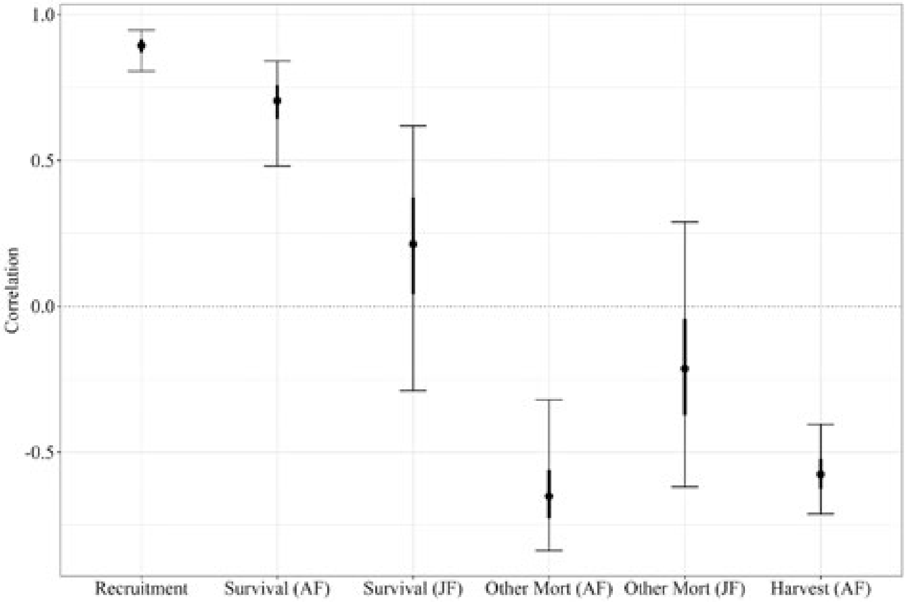


Figure 101. Correlation between annual pronghorn vital rate estimates (4-month recruitment, adult female [AF] survival, juvenile female [JF] survival, other mortality rates, and harvest rates) and population growth (lambda) in hunting district 620. Dots are mean correlation estimates, thin vertical bars are 95% credible intervals, and thick bars are 50% credible intervals. The dotted horizontal dotted line represents a correlation of 0 (i.e., where no correlation exists).

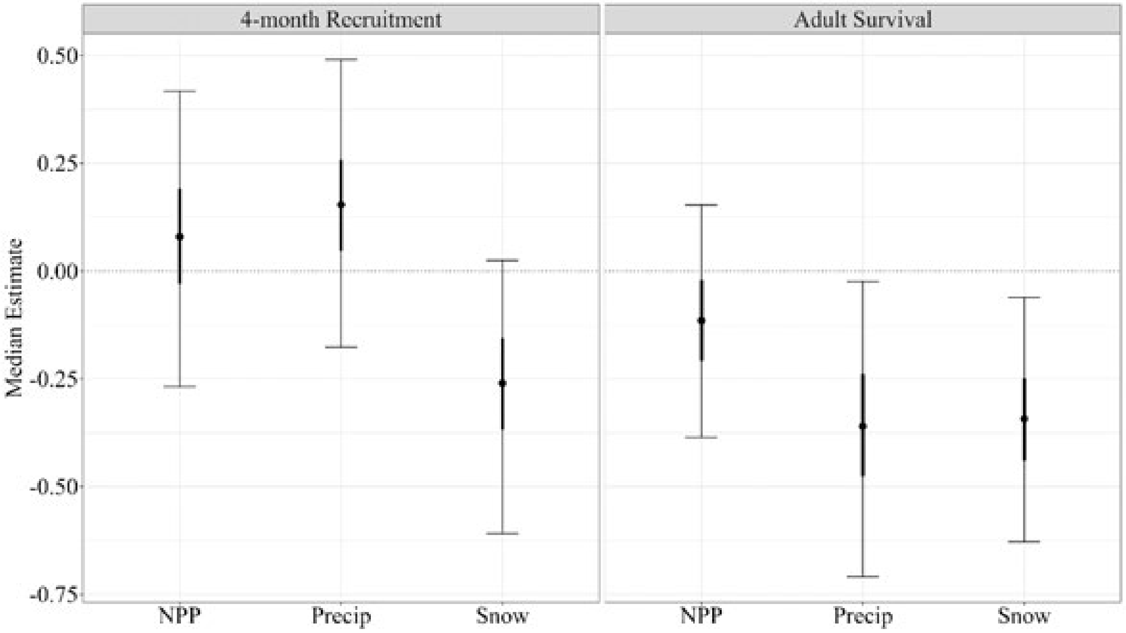


Figure 102. Beta estimates for covariates (net primary productivity [NPP], precipitation [Precip], and snow depth [Snow]) associated with pronghorn adult survival and 4-month recruitment in hunting district 620. Dots are median Beta estimates, thin vertical bars are 95% credible intervals, and thick bars are 50% credible intervals. The dotted horizontal dotted line represents a Beta estimate of 0 (i.e., where no effect exists).

HD 701

IPM results in HD 701 suggested a stable population since 2015, with a mean geometric lambda of 0.99 (0.97 – 1.02; Figure 103; Table 12; Appendix B). Estimated average adult female survival was 0.76 (0.72 – 0.80), adult male survival was 0.32 (0.25 – 0.39), and 4-month recruitment was 0.73 (0.62 – 0.85; Figure 104; Table 12). Annual lambda was most correlated with 4-month recruitment and adult female survival (Figure 105). Snow depth had a moderate association with 4-month recruitment (β = -0.24 [-0.58 – 0.08]), but there were no other strong effects (Table 13; Figure 106).

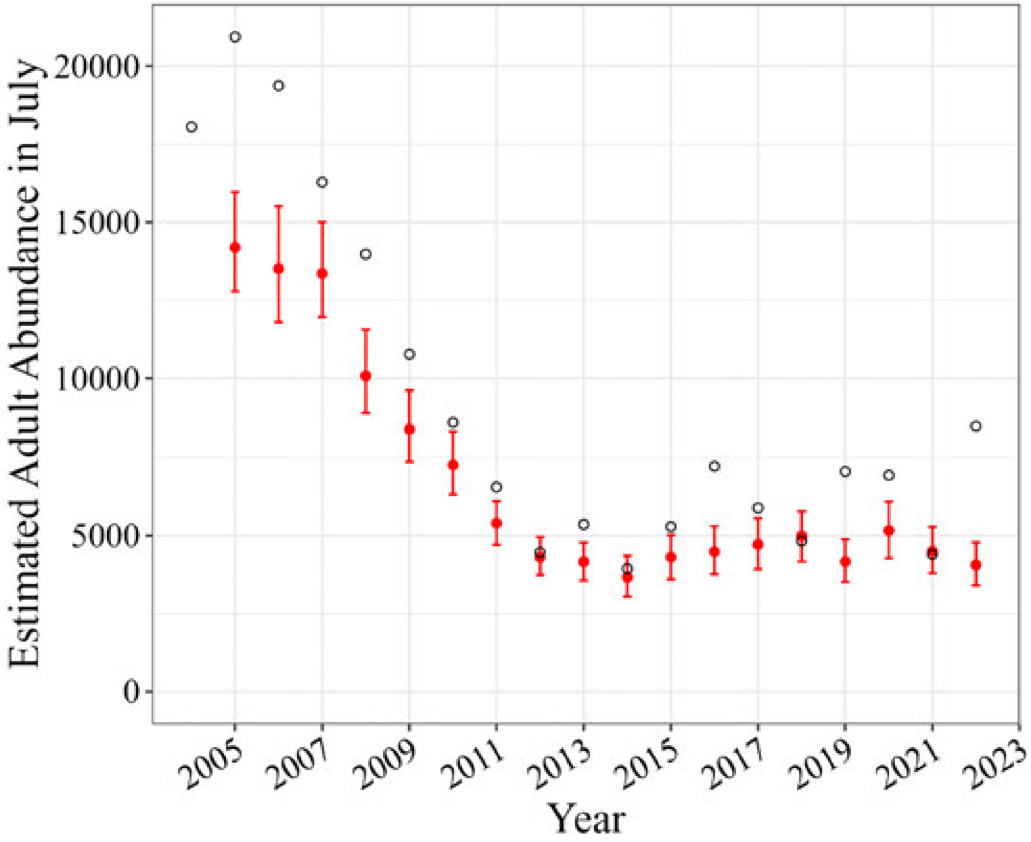


Figure 103. Pronghorn total July abundance in hunting district 701, estimated using an integrated population model. Red dots and error bars represent the mean abundance estimate with 95% credible intervals. Black dots represent the observed count, collected through aerial flights.

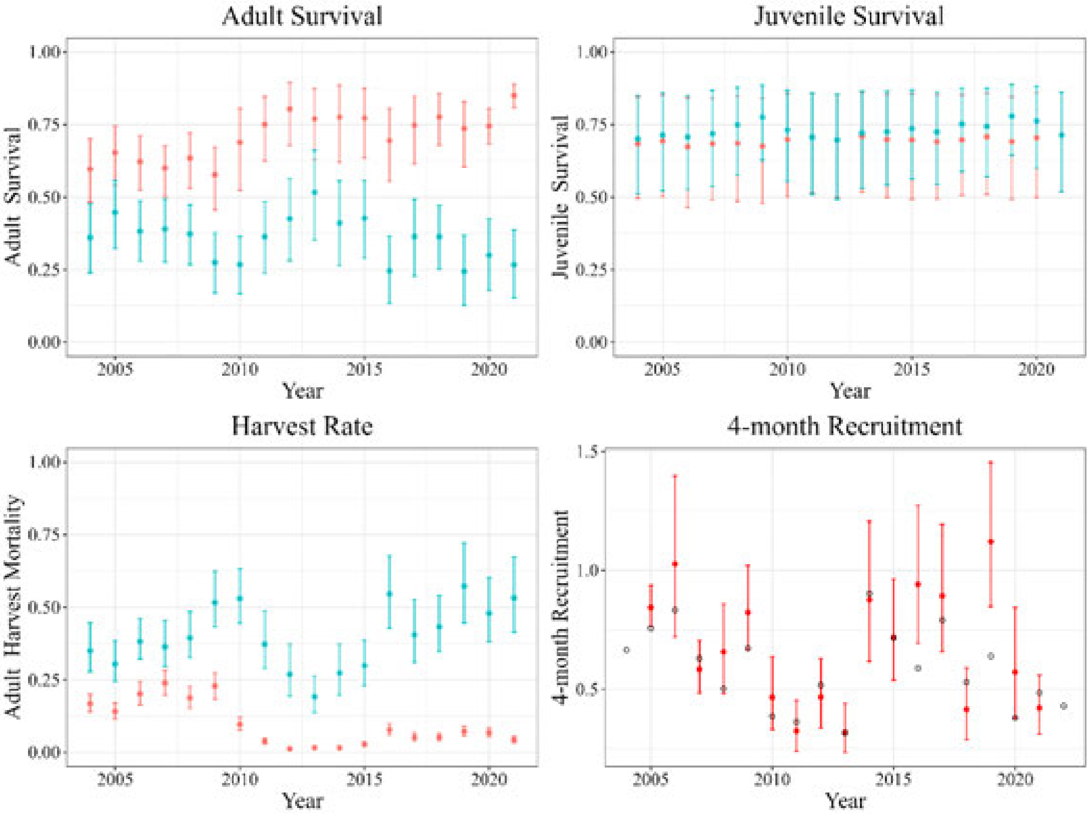


Figure 104. Pronghorn vital rate estimates in hunting district 701, estimated using an integrated population model. Salmon dots in adult survival, juvenile survival, and harvest rate panels represent females, while blue dots represent males. Black dots in the 4-month recruitment panel represent observed fawn:doe ratios. All error bars are 95% credible intervals.

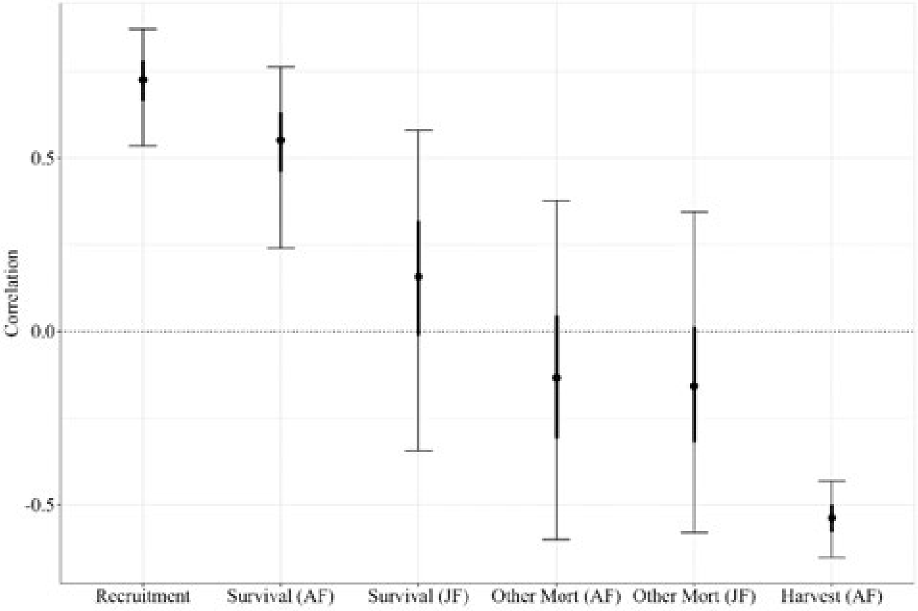


Figure 105. Correlation between annual pronghorn vital rate estimates (4-month recruitment, adult female [AF] survival, juvenile female [JF] survival, other mortality rates, and harvest rates) and population growth (lambda) in hunting district 701. Dots are mean correlation estimates, thin vertical bars are 95% credible intervals, and thick bars are 50% credible intervals. The dotted horizontal dotted line represents a correlation of 0 (i.e., where no correlation exists).

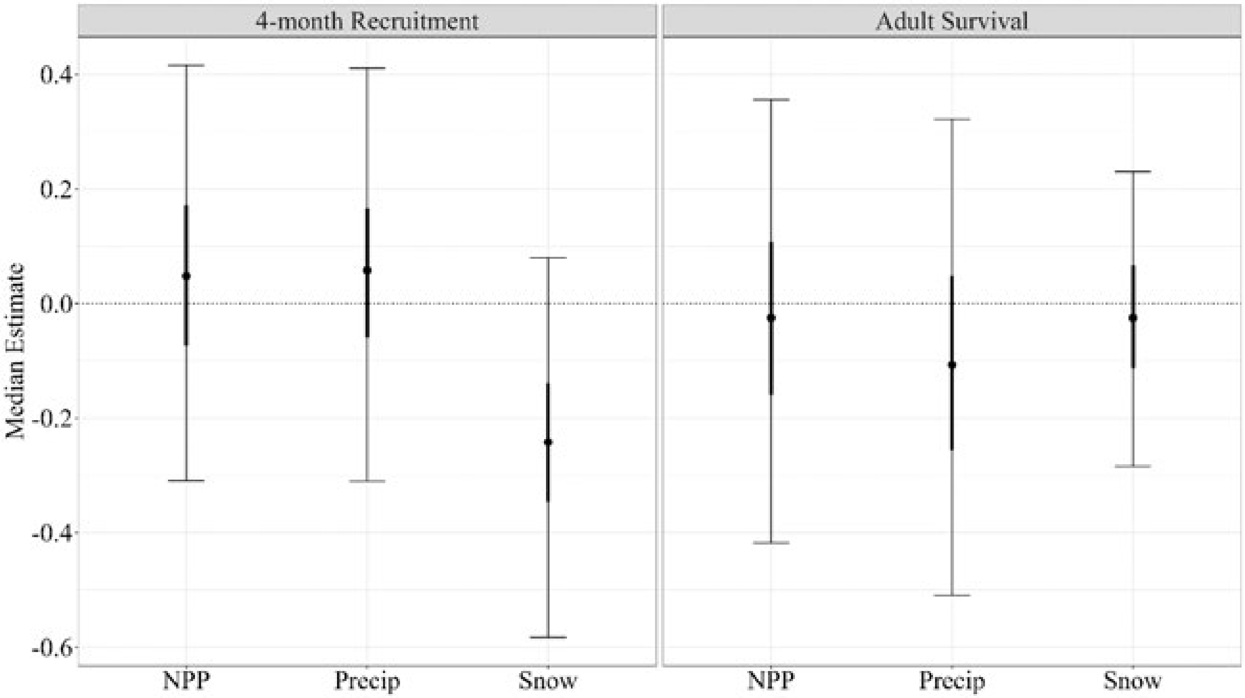


Figure 106. Beta estimates for covariates (net primary productivity [NPP], precipitation [Precip], and snow depth [Snow]) associated with pronghorn adult survival and 4-month recruitment in hunting district 701. Dots are median Beta estimates, thin vertical bars are 95% credible intervals, and thick bars are 50% credible intervals. The dotted horizontal dotted line represents a Beta estimate of 0 (i.e., where no effect exists).

HD 705

IPM results in HD 705 suggested an increasing population since 2015, with a mean geometric lambda of 1.06 (1.04 – 1.09; Figure 107; Table 12; Appendix B). Estimated average adult female survival was 0.75 (0.70 – 0.79), adult male survival was 0.31 (0.25 – 0.37), and 4-month recruitment was 1.00 (0.87 – 1.15; Figure 108; Table 12). Annual lambda was most correlated with 4-month recruitment and adult female survival (Figure 109). Snow depth had a moderate association with adult survival (β = -0.28 [-0.57 – 0.01]), but there were no other strong effects (Table 13; Figure 110).

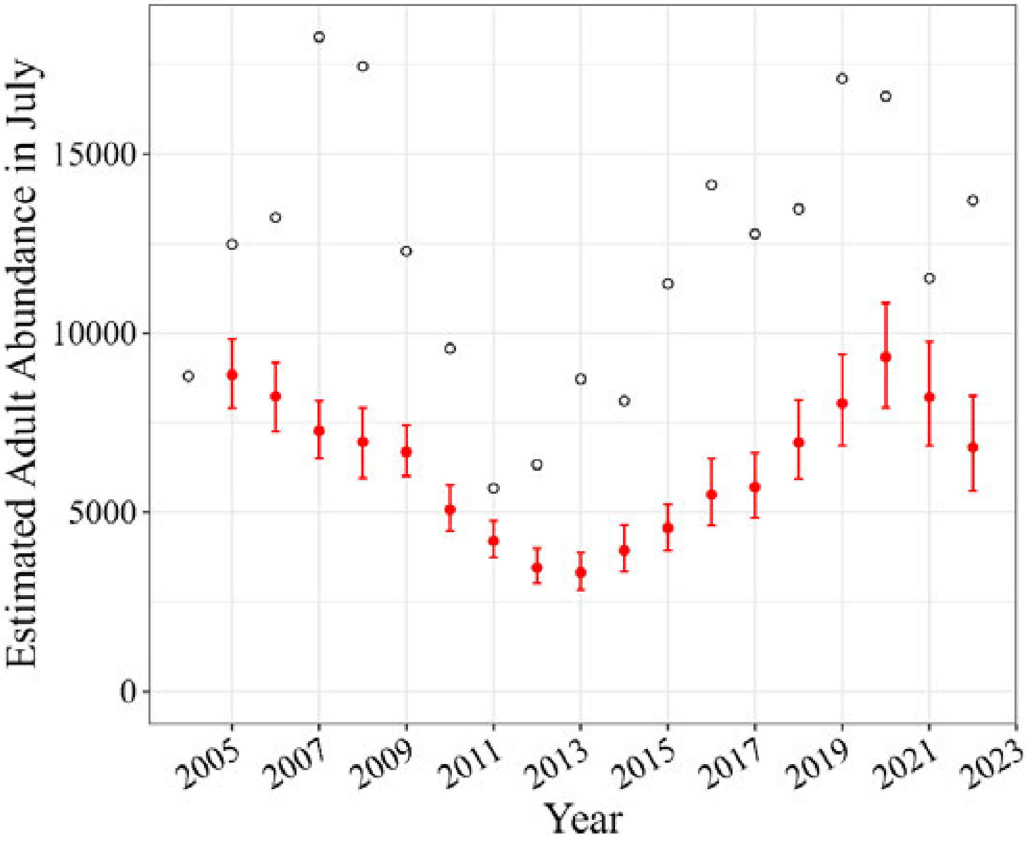


Figure 107. Pronghorn total July abundance in hunting district 705, estimated using an integrated population model. Red dots and error bars represent the mean abundance estimate with 95% credible intervals. Black dots represent the observed count, collected through aerial flights.

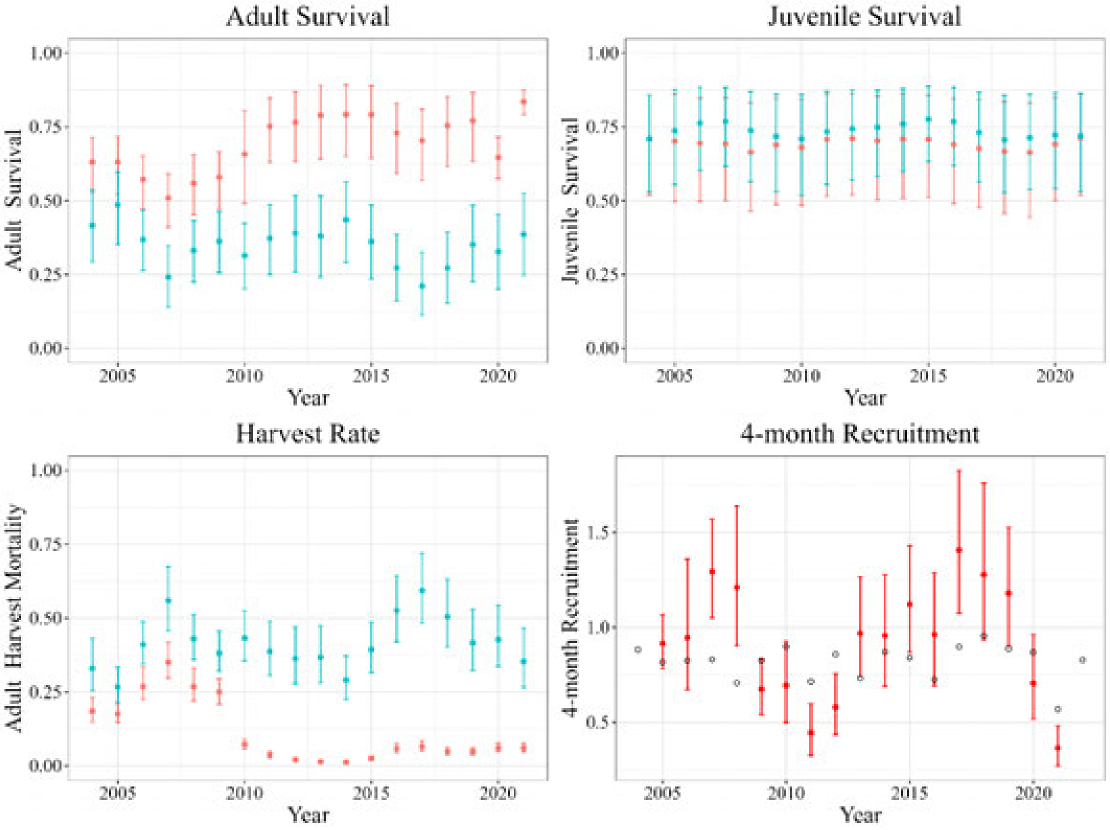


Figure 108. Pronghorn vital rate estimates in hunting district 705, estimated using an integrated population model. Salmon dots in adult survival, juvenile survival, and harvest rate panels represent females, while blue dots represent males. Black dots in the 4-month recruitment panel represent observed fawn:doe ratios. All error bars are 95% credible intervals.

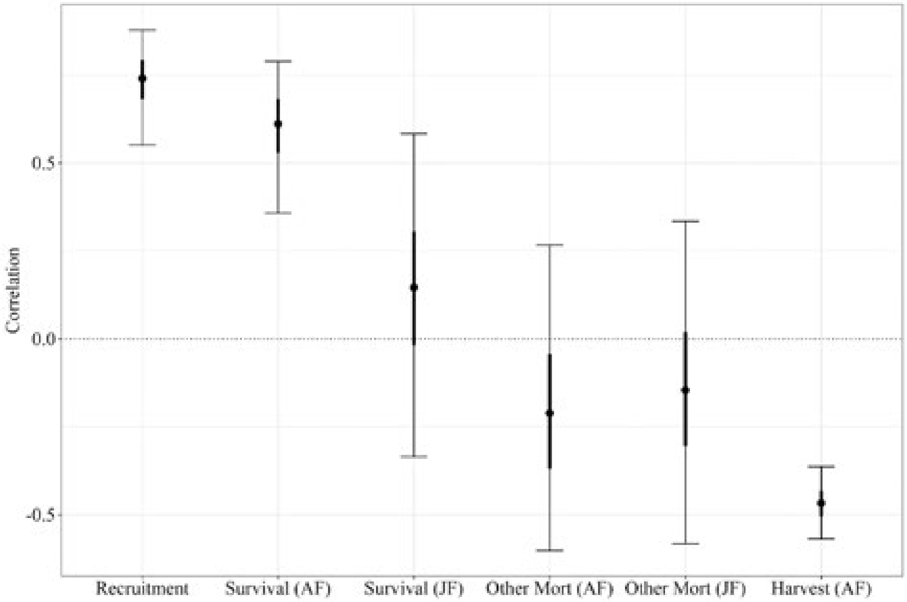


Figure 109. Correlation between annual pronghorn vital rate estimates (4-month recruitment, adult female [AF] survival, juvenile female [JF] survival, other mortality rates, and harvest rates) and population growth (lambda) in hunting district 705. Dots are mean correlation estimates, thin vertical bars are 95% credible intervals, and thick bars are 50% credible intervals. The dotted horizontal dotted line represents a correlation of 0 (i.e., where no correlation exists).

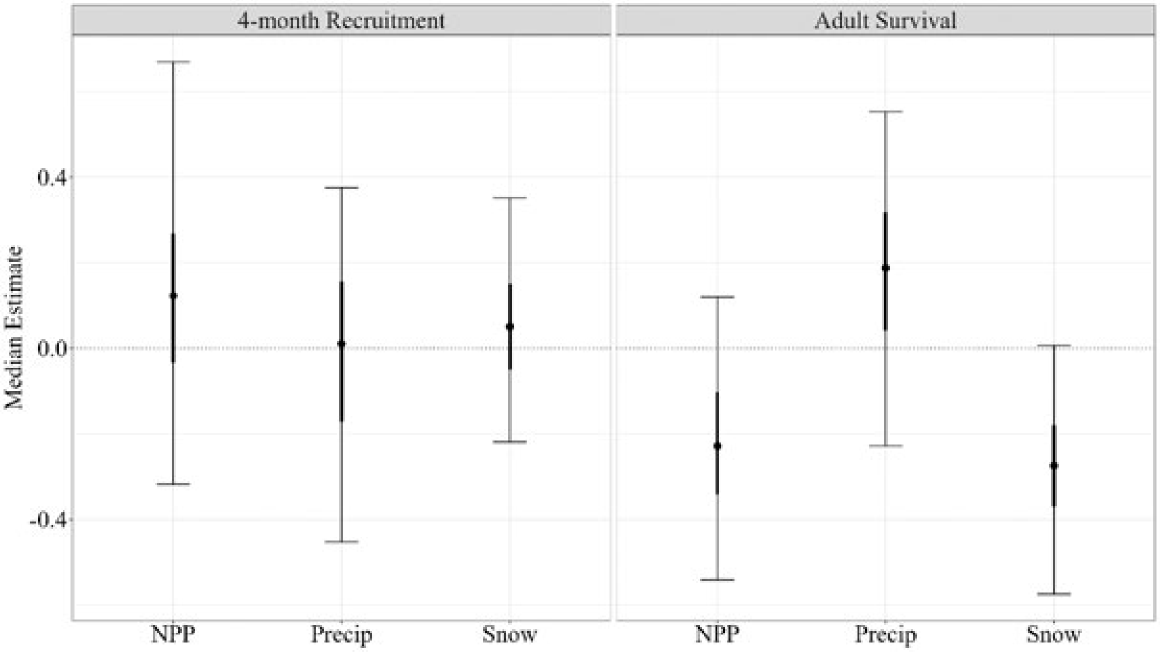


Figure 110. Beta estimates for covariates (net primary productivity [NPP], precipitation [Precip], and snow depth [Snow]) associated with pronghorn adult survival and 4-month recruitment in hunting district 705. Dots are median Beta estimates, thin vertical bars are 95% credible intervals, and thick bars are 50% credible intervals. The dotted horizontal dotted line represents a Beta estimate of 0 (i.e., where no effect exists).

Table 12. Integrated population model output, including mean pronghorn vital rate estimates (Mean) and 95% credible intervals (LCL and UCL) from 2016 (hunting district [HD] 313) or 2015 (all other HDs) through 2021/22 in 9 HDs across Montana. Lambda values represent the geometric mean across the time period.

HD	Vital Rate	Mean	LCL	UCL
313	Adult Female Survival	0.74	0.689	0.789
	Adult Male Survival	0.371	0.298	0.45
	Juvenile Female Survival	0.704	0.635	0.768
	Juvenile Male Survival	0.711	0.644	0.773
	Adult Female Harvest Rate	0.014	0.007	0.023
	Adult Male Harvest Rate	0.38	0.307	0.455
	Adult Female Other Mortality	0.246	0.2	0.294
	Adult Male Other Mortality	0.248	0.207	0.292
	Recruitment	0.522	0.353	0.757
	lambda	0.887	0.838	0.968
318	Adult Female Survival	0.722	0.689	0.752
	Adult Male Survival	0.392	0.325	0.462
	Juvenile Female Survival	0.73	0.667	0.787
	Juvenile Male Survival	0.691	0.623	0.755
	Adult Female Harvest Rate	0.121	0.106	0.135
	Adult Male Harvest Rate	0.336	0.279	0.391
	Adult Female Other Mortality	0.157	0.132	0.186
	Adult Male Other Mortality	0.273	0.229	0.317
	Recruitment	0.666	0.566	0.794
	lambda	0.938	0.91	0.977
360	Adult Female Survival	0.736	0.699	0.767
	Adult Male Survival	0.324	0.255	0.396
	Juvenile Female Survival	0.736	0.673	0.794
	Juvenile Male Survival	0.723	0.66	0.781
	Adult Female Harvest Rate	0.098	0.085	0.112

HD	Vital Rate	Mean	LCL	UCL
	Adult Male Harvest Rate	0.438	0.372	0.509
	Adult Female Other Mortality	0.167	0.141	0.196
	Adult Male Other Mortality	0.238	0.199	0.278
	Recruitment	0.587	0.522	0.679
	lambda	0.94	0.907	0.974
420	Adult Female Survival	0.832	0.81	0.852
	Adult Male Survival	0.521	0.471	0.568
	Juvenile Female Survival	0.726	0.664	0.782
	Juvenile Male Survival	0.734	0.678	0.788
	Adult Female Harvest Rate	0.031	0.027	0.036
	Adult Male Harvest Rate	0.236	0.212	0.262
	Adult Female Other Mortality	0.137	0.118	0.158
	Adult Male Other Mortality	0.243	0.205	0.283
	Recruitment	0.564	0.502	0.632
	lambda	1.034	1.016	1.052
481	Adult Female Survival	0.863	0.84	0.884
	Adult Male Survival	0.589	0.524	0.65
	Juvenile Female Survival	0.754	0.695	0.808
	Juvenile Male Survival	0.636	0.572	0.698
	Adult Female Harvest Rate	0.032	0.028	0.037
	Adult Male Harvest Rate	0.143	0.125	0.163
	Adult Female Other Mortality	0.105	0.085	0.126
	Adult Male Other Mortality	0.268	0.215	0.323
	Recruitment	0.691	0.58	0.786
	lambda	1.122	1.097	1.14
513	Adult Female Survival	0.831	0.787	0.868
	Adult Male Survival	0.512	0.403	0.625
	Juvenile Female Survival	0.715	0.648	0.776
	Juvenile Male Survival	0.712	0.648	0.772
	Adult Female Harvest Rate	0.02	0.017	0.024
	Adult Male Harvest Rate	0.2	0.163	0.243
	Adult Female Other Mortality	0.149	0.112	0.192
	Adult Male Other Mortality	0.287	0.195	0.381
	Recruitment	0.659	0.548	0.815
	lambda	1.034	1	1.069
620	Adult Female Survival	0.784	0.739	0.825
	Adult Male Survival	0.324	0.258	0.392
	Juvenile Female Survival	0.698	0.63	0.761
	Juvenile Male Survival	0.742	0.685	0.795
	Adult Female Harvest Rate	0.043	0.035	0.054
	Adult Male Harvest Rate	0.444	0.38	0.51
	Adult Female Other Mortality	0.172	0.137	0.212
	Adult Male Other Mortality	0.232	0.197	0.271
	Recruitment	0.819	0.682	0.984
	lambda	1.038	1.012	1.065
701	Adult Female Survival	0.761	0.718	0.802
	Adult Male Survival	0.316	0.252	0.385
	Juvenile Female Survival	0.701	0.632	0.765
	Juvenile Male Survival	0.745	0.688	0.796
	Adult Female Harvest Rate	0.056	0.047	0.066
	Adult Male Harvest Rate	0.467	0.402	0.535
	Adult Female Other Mortality	0.183	0.148	0.221
	Adult Male Other Mortality	0.217	0.183	0.252
	Recruitment	0.726	0.619	0.849

HD	Vital Rate	Mean	LCL	UCL
	lambda	0.992	0.969	1.017
705	Adult Female Survival	0.747	0.697	0.791
	Adult Male Survival	0.312	0.252	0.371
	Juvenile Female Survival	0.687	0.617	0.752
	Juvenile Male Survival	0.734	0.673	0.789
	Adult Female Harvest Rate	0.052	0.044	0.061
	Adult Male Harvest Rate	0.459	0.403	0.523
	Adult Female Other Mortality	0.201	0.162	0.245
	Adult Male Other Mortality	0.229	0.193	0.267
	Recruitment	1.003	0.87	1.154
	lambda	1.062	1.036	1.089

Table 13. Median beta estimates, 50% credible intervals (L50, U50), and 95% credible intervals (L95, U95) for covariates (net primary productivity [NPP], precipitation [Precip], and snow depth [Snow]) associated with pronghorn adult survival and 4-month recruitment across 9 hunting districts in Montana from 2004 – 2021/22.

HD	Covariate	Vital Rate	Median	L50	U50	L95	U95
313	NPP	4-month Recruitment	0.254	-0.223	0.715	-1.23	1.71
	NPP	Adult Survival	-0.154	-0.317	0.008	-0.62	0.32
	Snow	4-month Recruitment	0.078	-0.426	0.552	-1.55	1.51
	Snow	Adult Survival	0.067	-0.098	0.231	-0.41	0.55
	Precip	4-month Recruitment	-0.648	-1.146	-0.132	-2.13	1.08
	Precip	Adult Survival	1.559	1.257	1.877	0.70	2.55
318	NPP	4-month Recruitment	-0.044	-0.179	0.089	-0.49	0.35
	NPP	Adult Survival	0	-0.118	0.109	-0.36	0.31
	Snow	4-month Recruitment	0.053	-0.112	0.204	-0.43	0.51
	Snow	Adult Survival	-0.019	-0.119	0.077	-0.30	0.25
	Precip	4-month Recruitment	0.001	-0.133	0.121	-0.42	0.37
	Precip	Adult Survival	-0.07	-0.179	0.042	-0.38	0.26
360	NPP	4-month Recruitment	-0.02	-0.099	0.056	-0.26	0.21
	NPP	Adult Survival	-0.188	-0.272	-0.104	-0.43	0.07
	Snow	4-month Recruitment	0.081	0	0.16	-0.18	0.33
	Snow	Adult Survival	-0.205	-0.291	-0.115	-0.46	0.06
	Precip	4-month Recruitment	0.017	-0.058	0.091	-0.20	0.26
	Precip	Adult Survival	0.131	0.038	0.219	-0.13	0.38
420	NPP	4-month Recruitment	0.088	-0.058	0.236	-0.36	0.52
	NPP	Adult Survival	0.03	-0.06	0.123	-0.23	0.29
	Snow	4-month Recruitment	-0.129	-0.26	0	-0.54	0.26
	Snow	Adult Survival	0.054	-0.033	0.14	-0.18	0.28
	Precip	4-month Recruitment	0.019	-0.102	0.14	-0.36	0.41
	Precip	Adult Survival	-0.242	-0.37	-0.11	-0.62	0.12
481	NPP	4-month Recruitment	0.076	-0.094	0.244	-0.47	0.62
	NPP	Adult Survival	0.329	0.224	0.43	0.04	0.62
	Snow	4-month Recruitment	-0.15	-0.32	0.018	-0.71	0.36
	Snow	Adult Survival	0.457	0.347	0.569	0.13	0.78
	Precip	4-month Recruitment	-0.063	-0.224	0.094	-0.52	0.45
	Precip	Adult Survival	0.052	-0.076	0.178	-0.32	0.43
513	NPP	4-month Recruitment	0.079	-0.132	0.273	-0.50	0.67
	NPP	Adult Survival	0.521	0.348	0.698	-0.01	1.02
	Snow	4-month Recruitment	-0.024	-0.211	0.16	-0.58	0.57
	Snow	Adult Survival	-0.17	-0.342	-0.006	-0.72	0.32
	Precip	4-month Recruitment	0.162	-0.019	0.316	-0.38	0.63
	Precip	Adult Survival	-0.738	-0.94	-0.545	-1.32	-0.20
620	NPP	4-month Recruitment	0.08	-0.03	0.192	-0.27	0.42

HD	Covariate	Vital Rate	Median	L50	U50	L95	U95
	NPP	Adult Survival	-0.115	-0.208	-0.021	-0.39	0.15
	Snow	4-month Recruitment	-0.26	-0.368	-0.155	-0.61	0.03
	Snow	Adult Survival	-0.343	-0.44	-0.248	-0.63	-0.06
	Precip	4-month Recruitment	0.154	0.048	0.259	-0.18	0.49
	Precip	Adult Survival	-0.36	-0.475	-0.239	-0.71	-0.03
701	NPP	4-month Recruitment	0.048	-0.073	0.172	-0.31	0.42
	NPP	Adult Survival	-0.025	-0.159	0.108	-0.42	0.36
	Snow	4-month Recruitment	-0.242	-0.346	-0.139	-0.58	0.08
	Snow	Adult Survival	-0.025	-0.113	0.067	-0.28	0.23
	Precip	4-month Recruitment	0.058	-0.059	0.166	-0.31	0.41
	Precip	Adult Survival	-0.107	-0.256	0.049	-0.51	0.32
705	NPP	4-month Recruitment	0.123	-0.033	0.269	-0.32	0.67
	NPP	Adult Survival	-0.228	-0.341	-0.102	-0.54	0.12
	Snow	4-month Recruitment	0.051	-0.05	0.15	-0.22	0.35
	Snow	Adult Survival	-0.274	-0.369	-0.179	-0.57	0.01
	Precip	4-month Recruitment	0.011	-0.171	0.157	-0.45	0.38
	Precip	Adult Survival	0.188	0.043	0.318	-0.23	0.55

Summary across hunting districts

Overall, the western hunting (313, 318, 360) districts had decreasing pronghorn populations since 2015, while eastern hunting districts were either stable or increasing (Figure 111). Across hunting districts, the vital rate most associated with mean lambda was adult female survival. Generally, adult female survival rates >0.78 resulted in increasing populations (Figure 112). 4-month recruitment also had a small positive association with lambda, but this effect was relatively minor, compared to adult female survival. There were not strong patterns in the effects of covariates on pronghorn vital rates across Montana. However, snow appeared to have more of a negative effect on adult survival and 4-month recruitment in eastern hunting districts, while snow did not have as strong of an effect in western hunting districts (Figure 113).

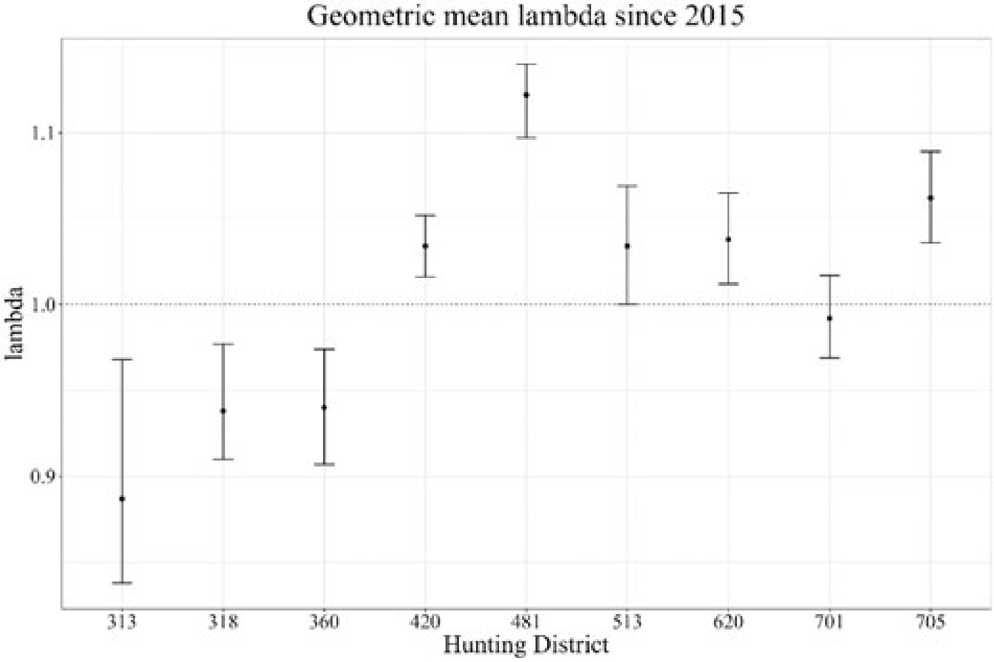


Figure 111. Pronghorn geometric mean lambda estimates since 2015 in each of 9 hunting districts across Montana. Black dots are the mean estimate, while error bars represent 95% credible intervals. The horizontal dotted line represents a stable population (lambda = 1).

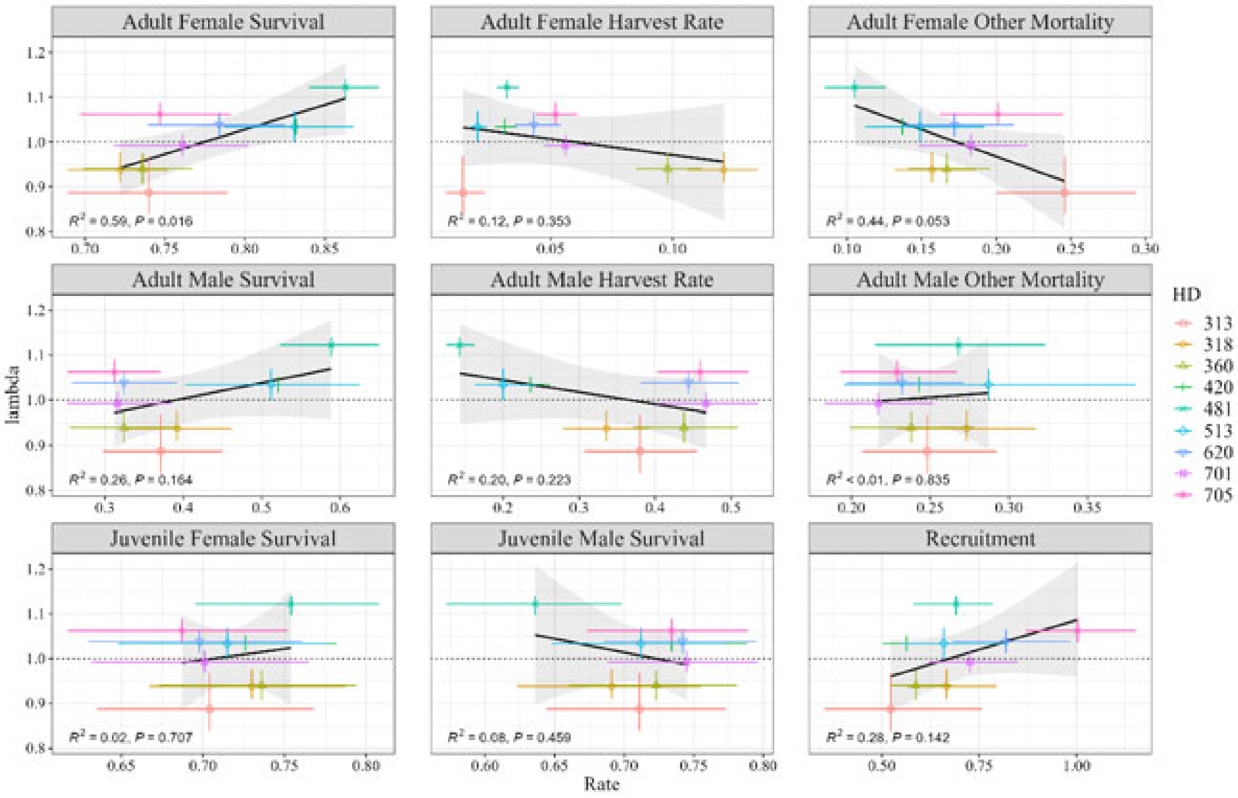


Figure 112. Correlations of mean vital rates with geometric mean lambda since 2015 across 9 hunting districts in Montana. Markers represent mean estimates for each hunting district and error bars represent 95% credible intervals. Black lines and gray error ribbons represent the best fit line through the estimates, and 95% confidence interval in the trend.

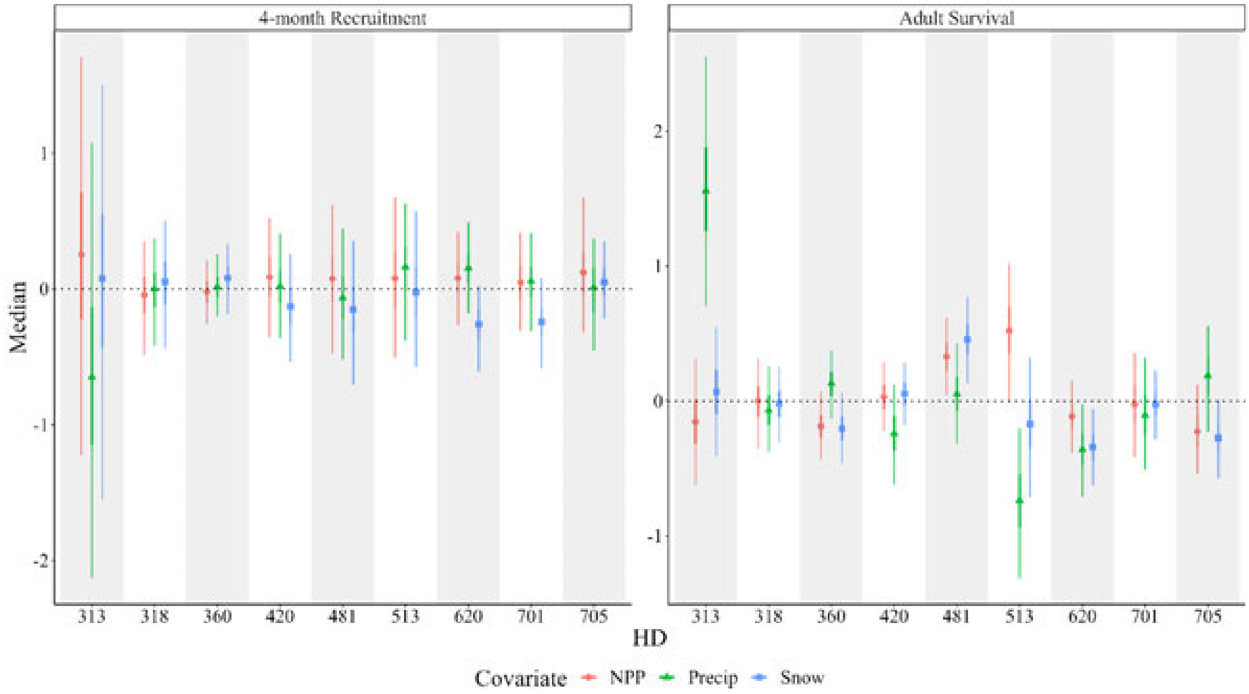


Figure 113. Beta estimates for covariates (net primary productivity [NPP], precipitation [Precip], and snow depth [Snow]) associated with pronghorn adult survival and 4-month recruitment across 9 hunting districts in Montana. Dots are median Beta estimates and vertical bars are 95% credible intervals. The dotted horizontal dotted line represents a Beta estimate of 0 (i.e., where no effect exists).

Discussion

Overall, our pronghorn vital rate estimates were within the range of estimates from other studies (Appendix A) and our findings suggest the most important vital rate driving pronghorn population dynamics was adult female survival. When adult female survival dropped below 0.75, 4-month recruitment had to be >0.7 to result in a stable or increasing population. In contrast, 4-month recruitment could be low (e.g., ~0.3) and still result in a stable or increasing population, if adult female survival was high (~0.9; Figure 114). The contributions of harvest and other, non-harvest, mortality to adult female survival varied by district. Most districts with adult female harvest rates <0.07 had stable or increasing populations. However, districts with high other adult female mortality (>~0.20), had decreasing populations, regardless of the harvest rate (e.g., HD 313). These findings suggest pronghorn management should prioritize adult female survival rates to achieve population objectives. Managers should consider the best management options for manipulating these rates, either through harvest or controlling other sources of mortality (see *Survival monitoring & analysis* section).

While 4-month recruitment estimates were reasonable, relative to past literature, they were often higher than observed fawn:doe ratios. We are uncertain why estimates tended to be higher than observed, but it could suggest July counts may not be adequately characterizing fawn:doe ratios. Alternatively, the model could be estimating recruitment above the observed values to account for increases in populations, given recruitment tends to have higher annual variation than adult female survival. Additional information regarding neonatal survival could help inform whether 4-month recruitment truly is higher than observed, or whether model specifications need to be altered. Further, there was limited data on juvenile survival and counts (only harvest), so the juvenile survival estimates largely resembled the prior information included in the model (male and female annual survival = 0.65). Thus, we recommend restricting inference from juvenile results unless additional information regarding juvenile survival is available.

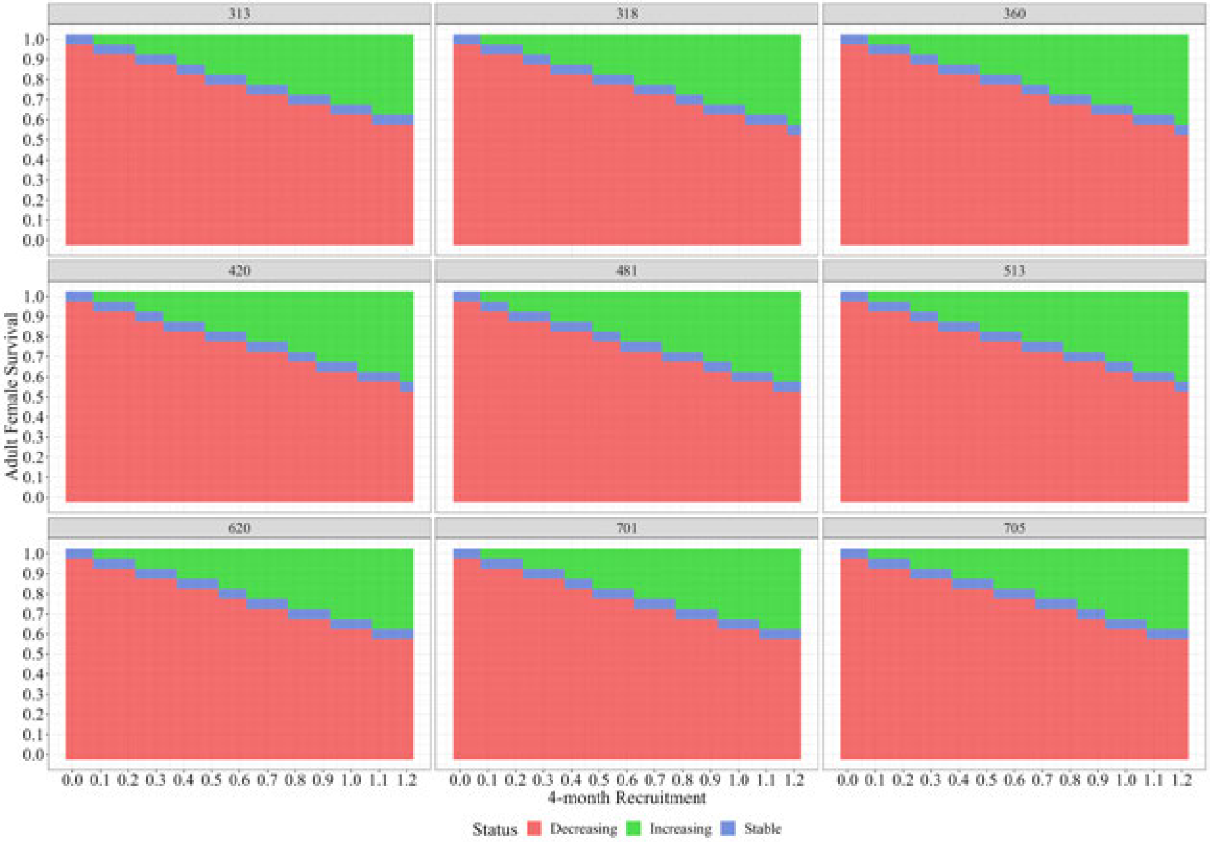


Figure 114. Predicted status of pronghorn populations in each of 9 hunting districts across Montana, given mean juvenile and adult male survival rates since 2015 and varying combinations of adult female survival and 4-month recruitment. Red areas represent decreasing populations (asymptotic lambda <1), blue areas represent stable populations (asymptotic lambda ~1), and green areas represent increasing populations (asymptotic lambda >1).

Our findings suggest there were no environmental conditions that had the same, consistent effect on pronghorn vital rates across their range in Montana. It is known that harsh winters can have negative effects on pronghorn populations (e.g., Reinking et al. 2018), but we only found strong or moderate negative effects of snow in 4 hunting districts (all eastern districts). This could be related to the fact that extremely "harsh" winters (e.g., snow depth >200% the 20-year average) never occurred in western hunting districts and only occurred a few times in eastern districts (Figure 115). It may take several harsh winter years for the models to identify a strong effect. This could also be true for other covariates we evaluated; if vital rates and/or environmental characteristics do not change greatly over time, it can be difficult to identify effects, particularly with low sample sizes. In this analysis, each year was equivalent to only one data point, which resulted in a sample size of only 20.

Alternatively, the effect of environmental conditions could affect pronghorn at smaller scales than our analysis could detect, or there could be other environmental characteristics that have strong effects on pronghorn that we did not include in models. We tested another measure of winter severity (Accumulated Winter Season Severity Index [AWSSI]; https://mrcc.purdue.edu/research/awssi), which accounts for max/min temperature, snowfall, and snow depth when quantifying winter severity. However, we found no differences in the direction (positive/negative) or statistical significance of the AWSSI effect, compared to our original snow depth covariate. Further investigation of additional factors potentially influencing pronghorn populations may be warranted; however, the nature of our dataset and modeling framework may limit our ability to identify true effects.

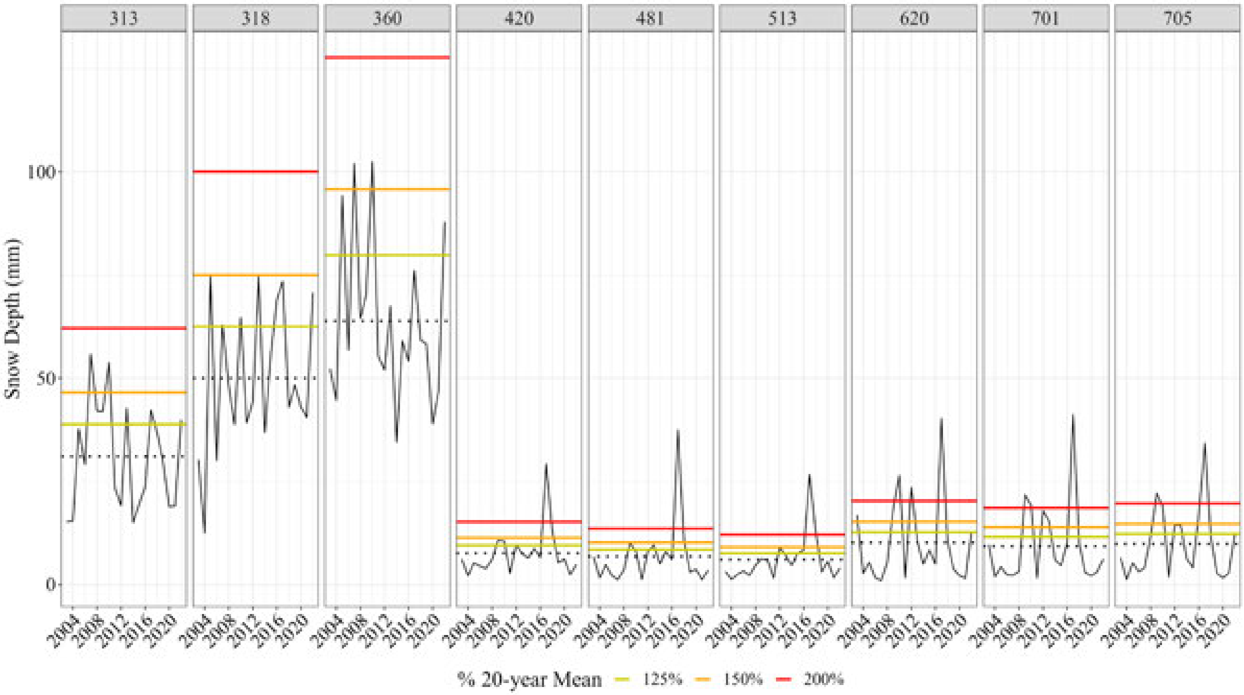


Figure 115. Mean cumulative snow depth in 9 hunting districts across Montana from 2004 – 2021. Black, dotted horizontal lines represent the 20-year mean snow depth for the hunting district. Green, orange, and red horizontal lines represent 125%, 150%, and 200% the 20-year average snow depth.

Overall, the IPM usually produced reasonable abundance estimates, relative to field observations; however, the IPM was highly sensitive to the observation distribution used for some hunting districts. Selection of the distribution for observations is an extremely important consideration when developing an IPM because it suggests what knowledge/confidence there is in the observations. For example, using a Normal distribution for aerial counts would suggest undercounting and overcounting individuals is equally likely and there is flexibility in the amount of uncertainty in counts. In contrast, using a Binomial distribution for aerial counts suggests the true population is greater than the counts. We made the assumption that aerial complete counts were minimum counts, which is why we used the Binomial distribution to characterize these counts. If this or other assumptions regarding observations are invalid, then our results may not accurately characterize populations.

IPM abundance estimates from hunting districts with only trend-extrapolated counts tended to differ more from field observations, potentially due to the low proportion of the hunting district the trend areas represented (HD 620 = 11%; HD 701 = 13%; HD 705 = 7%). Any change in the representativeness of these trend areas, relative to the entire hunting district, could cause large swings in the assumed total pronghorn abundance. We allowed flexibility in the proportion of area the trend areas represented, based on information gathered from other data included in the model. However, it is unknown how well the model-estimated trend area “representativeness” matched truth. Additional surveys that increase the proportion of area surveyed could help to reduce uncertainty in these estimates, assuming the additional area surveyed is representative of the hunting district. However, there would still be uncertainty regarding how well the trend areas represent the hunting district and the degree to which that representativeness changes from year to year.

Given the importance of understanding our knowledge and confidence in observations, we recommend assessing the current survey and inventory program for pronghorn. Adopting counting methods that provide uncertainty in counts (e.g., a distance sampling design) would reduce the guesswork involved in selecting observation distributions, which would likely result in more precise estimates of abundance from the IPM. Further, in hunting districts where pronghorn movement throughout the year is a concern, similarly-timed observations (e.g., counts and harvest) could improve model performance as this would ensure all observations are coming from the same population.

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

Objectives

Understanding resource selection is important for the management of species and their associated habitat. For pronghorn, the growing season, ranging from mid-March through July in Montana, encompasses the biological period of late gestation and early lactation, which is energetically expensive and important for annual reproductive output (O'Gara 2004*c*). Our research objectives were to 1) identify important spring and summer forage species, 2) evaluate pronghorn selection in relation to ground-based measurements of forage and fawn security resources, and 3) evaluate how selection behavior changes correspond with changing biological needs and spatiotemporal variations in plant communities within the summer. Here, we provide an overview of this study which has been incorporated into a manuscript for submission into a peer-review journal (Crane et al. *in prep*). Although we did not evaluate pronghorn selection during winter as part of this analysis, we also identify and present important winter forage species for general comparison with summer forage species.

Methods

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 types (i.e., grassland, shrubland, forest, and agriculture) within the annual range. We paired used and available sites based on sampling date to compare resources at used sites with resources available to pronghorn during the same time. At each sampling site, we measured and recorded vegetation attributes including species-specific percent cover, species-specific phenology, biomass of shrubs/forbs, and shrub/herbaceous plant height. At each sampling site, we collected forage samples consisting of the earliest two available phenological stages of forbs/shrubs. Given evidence from previous studies that indicate grass species are not an important part of pronghorn diet (Kessler et al. 1981, Pyrah 1987, Yoakum 2004*b*, Jacques et al. 2006), we excluded grasses from sampling. These samples were then analyzed to determine forage quality using in-vitro dry matter digestibility (DairyOne 2020) to estimate digestible energy (kcal/g).

In addition, we also collected spring/summer and winter fecal samples to determine important food items consumed by pronghorn. The spring/summer fecal samples were collected at known pronghorn collar locations and/or opportunistically within the study area. We combined fecal pellets into composite samples to achieve spatially and temporally balanced sampling. To distribute samples temporally, each year we targeted sampling of 5 composite samples during each of 9 sampling periods (i.e., 45 composite samples per year), each lasting 16 days, beginning late March (approximately on the 16th of each year). To distribute sampling across the study area, we prioritized collecting at least 1 sample from each of the 3 hunting districts overlapping the study area during each sampling period. We combined collected fecal pellets into composite samples such that each composite sample consisted of two pellets from each of 5 piles (>1 m apart). We combined composite samples in two separate ways: 1) we combined pellets from piles found within a 500 m^2 area or 2) we combined pellets collected during the same sampling period and within the same hunting district if there were not enough pellets collected within a 500 m^2 area. The winter fecal samples were collected from each captured and GPS-collared animal during January - March 2020 from all 8 study areas, for comparison across study areas and general comparison with the spring/summer diet results. We combined 1 pellet from 10 randomly selected individuals in each study area into a composite sample and assembled 2 composite samples per study area, resulting in 16 total composite samples. Both spring/summer and winter composite samples were thoroughly blended using a mortar and pestle prior to being placed in RNAlater stabilization solution in 50ml vials. The composite fecal samples were then analyzed using DNA metabarcoding (Species From Feces, Northern Arizona University).

The DNA metabarcoding results were used in a frequency of occurrence (FOO) analysis to develop a list of important forage species for pronghorn. FOO is generally considered a conservative approach to developing forage species lists as it limits the effect of taxa specific biases that impact marker signal (Deagle et al. 2018, Snobl et al. 2022). For each food item identified in the spring/summer composite samples, we calculated the percentage of samples which contained that forage item within each sampling period as well as the percentage of yearly samples containing that forage item. We developed thresholds of 5% yearly FOO and 40% sampling period FOO. To be included in the forage species list, each forage item had to meet the 5% yearly threshold during at least one year or the 40% sampling period threshold during at least one sampling period. This removed any forage items that appeared in two or fewer samples over an entire summer, unless that forage item appeared in multiple samples from within a single sampling period. For the winter composite samples, we calculated the percentage of composite samples which contained each forage species/item across study areas and within study areas.

To evaluate pronghorn resource selection during the summer, we compared resources at sites known to be used by pronghorn with those generally available in the study area. Using a combination of remotely-sensed and field data, we developed 19 covariates categorized into 5 groups containing variables related to time, anthropogenic features, forage availability, forage quality, and fawn security (Table 14). Covariates representing forage availability, forage quality, and fawn security were based on vegetation measurements and samples taken at vegetation sampling sites (Crane et al. *in prep*).

We correlated anthropogenic features and vegetation characteristics with relative probability of pronghorn selection using resource selection functions within a used-available study design (Manly et al. 2002). We paired used and available sites based on sampling date within a conditional logistic regression model framework to compare resources at used sites with resources available to pronghorn during the same time. Using a multi-stage modelling approach, we separately addressed research objectives. To understand overall pronghorn resource selection during summer, we developed a best-fit model without consideration of temporal variation (hereinafter referred to as the summer resource selection model). Next, to determine whether pronghorn resource selection varied during the spring and summer season, we built a time-varying model which included time interaction terms allowing selection to vary as a function of time (Wilson et al. 2014).

Table 14. Description of each covariate developed to represent variables expected to influence the summer resource selection of adult female pronghorn in central Montana, USA, 2021–2022. Covariates are divided into groups, each containing variables related to anthropogenic features, forage availability, forage quality, fawn security cover, and time. Each covariate is listed with a description of what the covariate value indicates. Covariates from all groups, excluding time, are listed with biological hypothesis associated with that covariate ("+" indicating selection, "–" indicating avoidance).

Covariate (units)	**Description**	**Biological hypothesis (+/–)**
Anthropogenic features		
Road density 500 m (m/km^2)	Density of paved/unpaved roads within 500m of a sampling site	–
Road density 1 km (m/km^2)	Density of paved/unpaved roads within 1km of a sampling site	–
Road density 2 km (m/km^2)	Density of paved/unpaved roads within 2km of a sampling site	–
Distance to road (m)	Distance (m) to nearest paved/unpaved road from a sampling site	–
Fence density 500 m (m/km^2)	Density of fences within 500m of a sampling site	–
Fence density 1 km (m/km^2)	Density of fences within 1km of a sampling site	–
Fence density 2 km (m/km^2)	Density of fences within 2km of a sampling site	–
Distance to fence (m)	Distance (m) to the nearest fence from a sampling site	–
Forage availability		
Forage cover (%)	Additive percent cover of forage species[a]	+
Forb biomass (g/m^2)	Biomass of annual and perennial forbs	+
Shrub biomass (g/m^2)	Biomass of shrubs	+
Forage quality		
Forb DE (kcal/g)	Digestible energy (DE) of forbs	+
Shrub DE (kcal/g)	DE of shrubs	+
Emergent forage cover (%)	Percent cover of emergent forage species at each sampling site	+
Fawn security cover		
Vegetation height (cm)	Maximum height of any vegetation (woody or herbaceous)	+
Shrub cover (%)	Additive percent cover of shrub species	+
Bare ground cover (%)	Additive percent cover of exposed soil, rock, litter, and lichen/moss/crust	–
Time		
Day of season (days)	Number of calendar days since beginning of sampling season starting with 1 on March 15 of each year	
Phenological day (days)	Number of calendar days until (negative values) or since (positive values) peak spring. Peak Spring (day 0) was identified each year by evaluating the relationship between forb biomass and day of season.	

[a] Forage species defined using fecal sample analysis.

Results

We sampled vegetation at 284 used and 284 available sampling sites resulting in 141 and 143 paired samples in 2021 and 2022, respectively. We identified 296 plant species from within 168 genera across all sampling sites. Common species included fringed sagewort (*Artemisia frigida*), Wyoming big sagebrush (*Artemisia tridentata*), common dandelion (*Taraxacum officinale*), scarlet globemallow (*Sphaeralcea coccinea*), western wheatgrass (*Pascopyrum smithii*), and Sandberg bluegrass (*Poa secunda*).

From the DNA metabarcoding of 87 fecal samples from spring/summer, we identified 74 species in 54 genera as forage species, including 54 forb, 14 shrub, and 6 grass species (Table 15). Of the forage species identified in the fecal samples, 56 species in 49 genera were sampled at the vegetation sites, consisting of 41 forb, 10 shrub, and 5 grass species. The number of forage species varied by sampling period, with the fewest average number of species occurring in late March ($\bar{x}$ = 13.0 species) and early April ($\bar{x}$ = 12.5 species; i.e., the first and second sampling periods) and increasing through time to a peak in June, with an average number of species of 31 in early June and 34 in late June (Table 16, Figure 116). Across this same time frame, the average number of forb species increased dramatically from ~3 to 26 species compared to shrub species that increased only from ~5 to 8 species and grass species that decreased from ~4 to 2 species.

Table 15. Summary of species composition of samples across years 2020 and 2021 for fecal samples analyzed using DNA metabarcoding. The percent mean for each species represents the average across years of the number of samples in which the species was detected divided by the total number of samples analyzed for each respective year (dashes occurring for standard deviation [SD] indicate the species was detected in only one year).

		Percent (%)					
Species	**Growth Form**	**Mean**	**SD**	**Min**	**Max**	**No. of Periods**	**No. of Samples**
Artemisia sp.	Shrub	72.4	1.3	71.4	73.3	18	72
Artemisia cana	Shrub	60.9	1.9	59.5	62.2	16	53
Rosa sp.	Shrub	56.2	5.4	52.4	60.0	15	49
Taraxacum sp.	Forb	55.3	5.9	51.1	59.5	15	48
Symphyotrichum sp.	Forb	36.7	1.5	35.7	37.8	13	35
Sphaeralcea coccinea	Forb	34.6	4.9	31.1	38.1	11	30
Oenothera suffrutescens	Forb	33.6	9.8	26.7	40.5	12	29
Poa nemoralis	Grass	31.2	6.4	26.7	35.7	11	27
Comandra umbellata	Forb	29.8	5.1	26.2	33.3	12	26
Eriogonum sp.	Forb	29.8	1.8	28.6	31.1	12	26
Atriplex sp.	Shrub	29.1	16.1	17.8	40.5	13	27
Tragopogon pratensis	Forb	29.0	9.5	22.2	35.7	10	25
Geocaulon lividum	Forb	28.7	3.5	26.2	31.1	11	25
Poa sp.	Grass	28.5	10.0	21.4	35.6	10	30
Medicago sp.	Forb	25.5	7.7	20.0	31.0	13	22
Lactuca sp.	Forb	23.1	4.4	20.0	26.2	10	20
Sarcobatus vermiculatus	Shrub	22.9	2.1	21.4	24.4	12	20
Tragopogon dubius	Forb	20.9	7.5	15.6	26.2	8	18
Atriplex patula	Shrub	19.7	5.8	15.6	23.8	9	17
Convolvulus arvensis	Forb	19.5	0.7	19.0	20.0	8	17
Glycyrrhiza lepidota	Forb	19.5	0.7	19.0	20.0	9	17
Polygonum aviculare	Forb	18.3	2.4	16.7	20.0	9	16
Dalea purpurea	Forb	17.5	9.0	11.1	23.8	7	15
Rumex acetosella	Forb	15.1	5.6	11.1	19.0	6	13
Lomatium sp.	Forb	14.8	7.4	9.5	20.0	8	13
Ericameria sp.	Shrub	13.9	3.9	11.1	16.7	9	12
Poa pratensis	Grass	13.3	--	13.3	13.3	4	6
Potentilla sp.	Forb	13.3	--	13.3	13.3	3	6
Erigeron pumilus	Forb	11.9	--	11.9	11.9	2	5
Bromus sp.	Grass	11.5	0.6	11.1	11.9	8	11
Eriogonum pauciflorum	Forb	11.1	--	11.1	11.1	4	5
Euphorbia sp.	Forb	10.2	4.4	7.1	13.3	5	10
Rhus sp.	Shrub	10.2	4.4	7.1	13.3	5	9
Achillea sp.	Forb	9.5	--	9.5	9.5	3	4
Heterotheca sp.	Forb	9.5	--	9.5	9.5	2	4
Juniperus communis	Shrub	9.5	--	9.5	9.5	3	4
Opuntia fragilis	Forb	9.5	--	9.5	9.5	3	4
Symphyotrichum novae-angliae	Forb	9.5	--	9.5	9.5	3	4
Triticum aestivum	Grass	8.9	--	8.9	8.9	3	4
Oenothera sp.	Forb	8.1	2.0	6.7	9.5	5	17
Chamaesyce sp.	Forb	7.1	--	7.1	7.1	2	3
Gutierrezia sp.	Shrub	7.1	--	7.1	7.1	3	3
Lygodesmia juncea	Forb	7.1	--	7.1	7.1	2	3
Packera sp.	Forb	7.1	--	7.1	7.1	2	3
Sphaeralcea sp.	Forb	7.1	--	7.1	7.1	3	8

		Percent (%)					
Species	**Growth Form**	**Mean**	**SD**	**Min**	**Max**	**No. of Periods**	**No. of Samples**
Chenopodium sp.	Forb	6.9	0.3	6.7	7.1	5	7
Erigeron sp.	Forb	6.9	0.3	6.7	7.1	4	6
Geum sp.	Forb	6.9	0.3	6.7	7.1	5	6
Androsace sp.	Forb	6.7	--	6.7	6.7	3	3
Astragalus gracilis	Forb	6.7	--	6.7	6.7	2	3
Bassia scoparia	Forb	6.7	--	6.7	6.7	2	3
Carex sp.	Grass	6.7	--	6.7	6.7	2	3
Chenopodium album	Forb	6.7	--	6.7	6.7	2	3
Helianthus tuberosus	Forb	6.7	--	6.7	6.7	2	3
Lepidium sp.	Forb	6.7	--	6.7	6.7	2	3
Ribes aureum	Shrub	6.7	--	6.7	6.7	2	3
Ribes sp.	Shrub	6.7	--	6.7	6.7	2	3
Symphoricarpos occidentalis	Shrub	6.7	--	6.7	6.7	3	3
Vicia sp.	Forb	6.7	--	6.7	6.7	2	3
Astragalus sp.	Forb	4.8	--	4.8	4.8	1	3
Penstemon sp.	Forb	4.8	--	4.8	4.8	1	1
Scorzonera laciniata	Forb	4.8	--	4.8	4.8	1	2
Scorzonera sp.	Forb	4.8	--	4.8	4.8	1	2
Tetraneuris acaulis	Forb	4.8	--	4.8	4.8	1	2
Helianthus sp.	Forb	4.6	0.2	4.4	4.8	2	4
Bassia sp.	Forb	4.4	--	4.4	4.4	1	2
Grindelia sp.	Forb	4.4	--	4.4	4.4	1	2
Lepidium densiflorum	Forb	4.4	--	4.4	4.4	1	2
Viola purpurea	Forb	4.4	--	4.4	4.4	1	2
Picradeniopsis oppositifolia	Forb	3.4	1.5	2.4	4.4	2	3
Salsola sp.	Forb	3.4	1.5	2.4	4.4	2	3
Juniperus sp.	Shrub	2.4	--	2.4	2.4	1	2
Convolvulus sp.	Forb	2.2	--	2.2	2.2	1	4
Rumex sp.	Forb	2.2	--	2.2	2.2	1	2

Table 16. Summary (percent mean and range) of forage species for each sampling period across years 2020 and 2021 for fecal samples analyzed using DNA metabarcoding. The percent mean for each species and period represents the average across years of the number of samples in each period in which the species was detected divided by the total number of samples analyzed in that period for each respective year. "Early" month timings generally represent the 1st to the 15th day of each month.

		Mean percent (%) and range (min – max)								
Taxon	**Growth Form**	**Late March**	**Early April**	**Late April**	**Early May**	**Late May**	**Early June**	**Late June**	**Early July**	**Late July**
Artemisia cana	Shrub	90 (80-100)	80 (80-80)	100 (100-100)	80 (80-80)	30 (20-40)	60 (60-60)	40 (40-40)	60 (60-60)	20 (20-20)
Artemisia sp.	Shrub	90 (80-100)	80 (80-80)	100 (100-100)	90 (80-100)	60 (40-80)	80 (80-80)	70 (60-80)	90 (80-100)	90 (80-100)
Rosa sp.	Shrub	20 (20-20)	20 (20-20)	40 (40-40)	70 (60-80)	70 (40-100)	80 (60-100)	90 (80-100)	90 (80-100)	65 (50-80)
Taraxacum sp.	Forb	20 (20-20)	30 (20-40)	70 (60-80)	60 (40-80)	100 (100-100)	80 (60-100)	80 (80-80)	60 (60-60)	100 (100-100)
Poa nemoralis	Grass	70 (40-100)	70 (40-100)	50 (40-60)	20 (20-20)	80 (80-80)	20 (20-20)	20 (20-20)	20 (20-20)	--
Atriplex sp.	Shrub	50 (40-60)	60 (60-60)	50 (20-80)	60 (60-60)	40 (40-40)	60 (60-60)	20 (20-20)	20 (20-20)	--
Eriogonum sp.	Forb	40 (20-60)	40 (40-40)	20 (20-20)	80 (80-80)	40 (20-60)	50 (40-60)	60 (60-60)	20 (20-20)	--
Medicago sp.	Forb	--	30 (20-40)	20 (20-20)	30 (20-40)	70 (60-80)	40 (20-60)	20 (20-20)	20 (20-20)	50 (50-50)
Atriplex patula	Shrub	30 (20-40)	60 (60-60)	40 (40-40)	40 (20-60)	20 (20-20)	60 (60-60)	20 (20-20)	--	--
Symphyotrichum sp.	Forb	20 (20-20)	--	--	20 (20-20)	30 (20-40)	70 (60-80)	70 (60-80)	100 (100-100)	65 (50-80)
Tragopogon pratensis	Forb	20 (20-20)	--	20 (20-20)	--	60 (40-80)	90 (80-100)	40 (40-40)	60 (60-60)	50 (50-50)
Sarcobatus vermiculatus	Shrub	--	--	50 (40-60)	40 (40-40)	20 (20-20)	40 (20-60)	20 (20-20)	30 (20-40)	35 (20-50)
Comandra umbellata	Forb	--	--	40 (40-40)	60 (20-100)	50 (40-60)	50 (40-60)	40 (20-60)	40 (40-40)	35 (20-50)
Geocaulon lividum	Forb	--	--	40 (40-40)	60 (20-100)	50 (40-60)	40 (40-40)	60 (60-60)	40 (40-40)	45 (40-50)
Ericameria sp.	Shrub	--	--	20 (20-20)	20 (20-20)	40 (40-40)	20 (20-20)	40 (40-40)	20 (20-20)	60 (20-100)
Poa sp.	Grass	80 (60-100)	70 (40-100)	70 (60-80)	60 (60-60)	--	--	--	40 (20-60)	20 (20-20)
Lomatium sp.	Forb	--	20 (20-20)	40 (40-40)	60 (60-60)	30 (20-40)	20 (20-20)	20 (20-20)	--	--
Convolvulus arvensis	Forb	--	--	20 (20-20)	--	20 (20-20)	30 (20-40)	40 (40-40)	80 (80-80)	40 (40-40)
Oenothera suffrutescens	Forb	--	--	--	30 (20-40)	30 (20-40)	80 (60-100)	60 (40-80)	60 (60-60)	60 (20-100)
Sphaeralcea coccinea	Forb	--	--	--	30 (20-40)	40 (40-40)	50 (40-60)	90 (80-100)	70 (60-80)	55 (50-60)
Bromus sp.	Grass	40 (40-40)	20 (20-20)	--	30 (20-40)	--	20 (20-20)	20 (20-20)	--	--
Geum sp.	Forb	20 (20-20)	20 (20-20)	20 (20-20)	40 (40-40)	--	--	20 (20-20)	--	--
Rumex acetosella	Forb	--	--	60 (60-60)	20 (20-20)	30 (20-40)	80 (80-80)	--	--	40 (40-40)
Glycyrrhiza lepidota	Forb	--	--	--	--	40 (40-40)	50 (20-80)	30 (20-40)	40 (20-60)	45 (40-50)
Lactuca sp.	Forb	--	--	--	--	30 (20-40)	50 (20-80)	40 (20-60)	60 (60-60)	35 (20-50)
Polygonum aviculare	Forb	--	--	--	--	20 (20-20)	40 (40-40)	50 (40-60)	30 (20-40)	45 (40-50)
Tragopogon dubius	Forb	--	--	--	--	20 (20-20)	80 (80-80)	40 (40-40)	60 (60-60)	50 (50-50)
Poa pratensis	Grass	60 (60-60)	--	--	--	--	--	20 (20-20)	20 (20-20)	20 (20-20)
Rhus sp.	Shrub	20 (20-20)	--	--	--	--	40 (40-40)	40 (40-40)	40 (20-60)	--
Eriogonum pauciflorum	Forb	--	--	--	40 (40-40)	20 (20-20)	20 (20-20)	--	--	20 (20-20)
Oenothera sp.	Forb	--	--	--	40 (40-40)	60 (60-60)	80 (60-100)	80 (80-80)	--	--
Dalea purpurea	Forb	--	--	--	--	--	40 (40-40)	50 (40-60)	50 (40-60)	60 (20-100)
Chenopodium sp.	Forb	--	--	--	--	--	20 (20-20)	60 (60-60)	20 (20-20)	35 (20-50)
Juniperus communis	Shrub	40 (40-40)	20 (20-20)	20 (20-20)	--	--	--	--	--	--
Opuntia fragilis	Forb	20 (20-20)	--	20 (20-20)	40 (40-40)	--	--	--	--	--
Gutierrezia sp.	Shrub	--	20 (20-20)	--	20 (20-20)	20 (20-20)	--	--	--	--

		Mean percent (%) and range (min – max)								
Taxon	**Growth Form**	**Late March**	**Early April**	**Late April**	**Early May**	**Late May**	**Early June**	**Late June**	**Early July**	**Late July**
Sphaeralcea sp.	Forb	--	20 (20-20)	--	--	--	60 (60-60)	80 (80-80)	--	--
Achillea sp.	Forb	--	--	20 (20-20)	--	40 (40-40)	20 (20-20)	--	--	--
Androsace sp.	Forb	--	--	--	20 (20-20)	20 (20-20)	20 (20-20)	--	--	--
Potentilla sp.	Forb	--	--	--	20 (20-20)	--	--	60 (60-60)	40 (40-40)	--
Symphoricarpos occidentalis	Shrub	--	--	--	20 (20-20)	20 (20-20)	--	20 (20-20)	--	--
Erigeron sp.	Forb	--	--	--	--	20 (20-20)	--	--	30 (20-40)	40 (40-40)
Symphyotrichum novae-angliae	Forb	--	--	--	--	--	40 (40-40)	20 (20-20)	20 (20-20)	--
Triticum aestivum	Grass	--	--	--	--	--	40 (40-40)	20 (20-20)	--	20 (20-20)
Euphorbia sp.	Forb	--	--	--	--	--	--	30 (20-40)	50 (40-60)	40 (40-40)
Carex sp.	Grass	20 (20-20)	--	40 (40-40)	--	--	--	--	--	--
Vicia sp.	Forb	--	--	20 (20-20)	--	--	--	40 (40-40)	--	--
Ribes aureum	Shrub	--	--	--	40 (40-40)	20 (20-20)	--	--	--	--
Ribes sp.	Shrub	--	--	--	40 (40-40)	20 (20-20)	--	--	--	--
Astragalus gracilis	Forb	--	--	--	20 (20-20)	--	--	40 (40-40)	--	--
Lepidium sp.	Forb	--	--	--	--	20 (20-20)	--	40 (40-40)	--	--
Lygodesmia juncea	Forb	--	--	--	--	20 (20-20)	40 (40-40)	--	--	--
Erigeron pumilus	Forb	--	--	--	--	--	60 (60-60)	40 (40-40)	--	--
Heterotheca sp.	Forb	--	--	--	--	--	40 (40-40)	--	40 (40-40)	--
Chenopodium album	Forb	--	--	--	--	--	20 (20-20)	40 (40-40)	--	--
Bassia scoparia	Forb	--	--	--	--	--	--	40 (40-40)	20 (20-20)	--
Helianthus sp.	Forb	--	--	--	--	--	--	40 (40-40)	40 (40-40)	--
Helianthus tuberosus	Forb	--	--	--	--	--	--	40 (40-40)	--	20 (20-20)
Picradeniopsis oppositifolia	Forb	--	--	--	--	--	--	40 (40-40)	--	50 (50-50)
Salsola sp.	Forb	--	--	--	--	--	--	40 (40-40)	--	50 (50-50)
Chamaesyce sp.	Forb	--	--	--	--	--	--	20 (20-20)	40 (40-40)	--
Packera sp.	Forb	--	--	--	--	--	--	20 (20-20)	40 (40-40)	--
Juniperus sp.	Shrub	--	40 (40-40)	--	--	--	--	--	--	--
Astragalus sp.	Forb	--	--	--	--	--	60 (60-60)	--	--	--
Scorzonera laciniata	Forb	--	--	--	--	--	40 (40-40)	--	--	--
Scorzonera sp.	Forb	--	--	--	--	--	40 (40-40)	--	--	--
Tetraneuris acaulis	Forb	--	--	--	--	--	40 (40-40)	--	--	--
Bassia sp.	Forb	--	--	--	--	--	--	40 (40-40)	--	--
Grindelia sp.	Forb	--	--	--	--	--	--	40 (40-40)	--	--
Lepidium densiflorum	Forb	--	--	--	--	--	--	40 (40-40)	--	--
Viola purpurea	Forb	--	--	--	--	--	--	40 (40-40)	--	--
Convolvulus sp.	Forb	--	--	--	--	--	--	--	80 (80-80)	--
Penstemon sp.	Forb	--	--	--	--	--	--	--	--	50 (50-50)
Rumex sp.	Forb	--	--	--	--	--	--	--	--	40 (40-40)

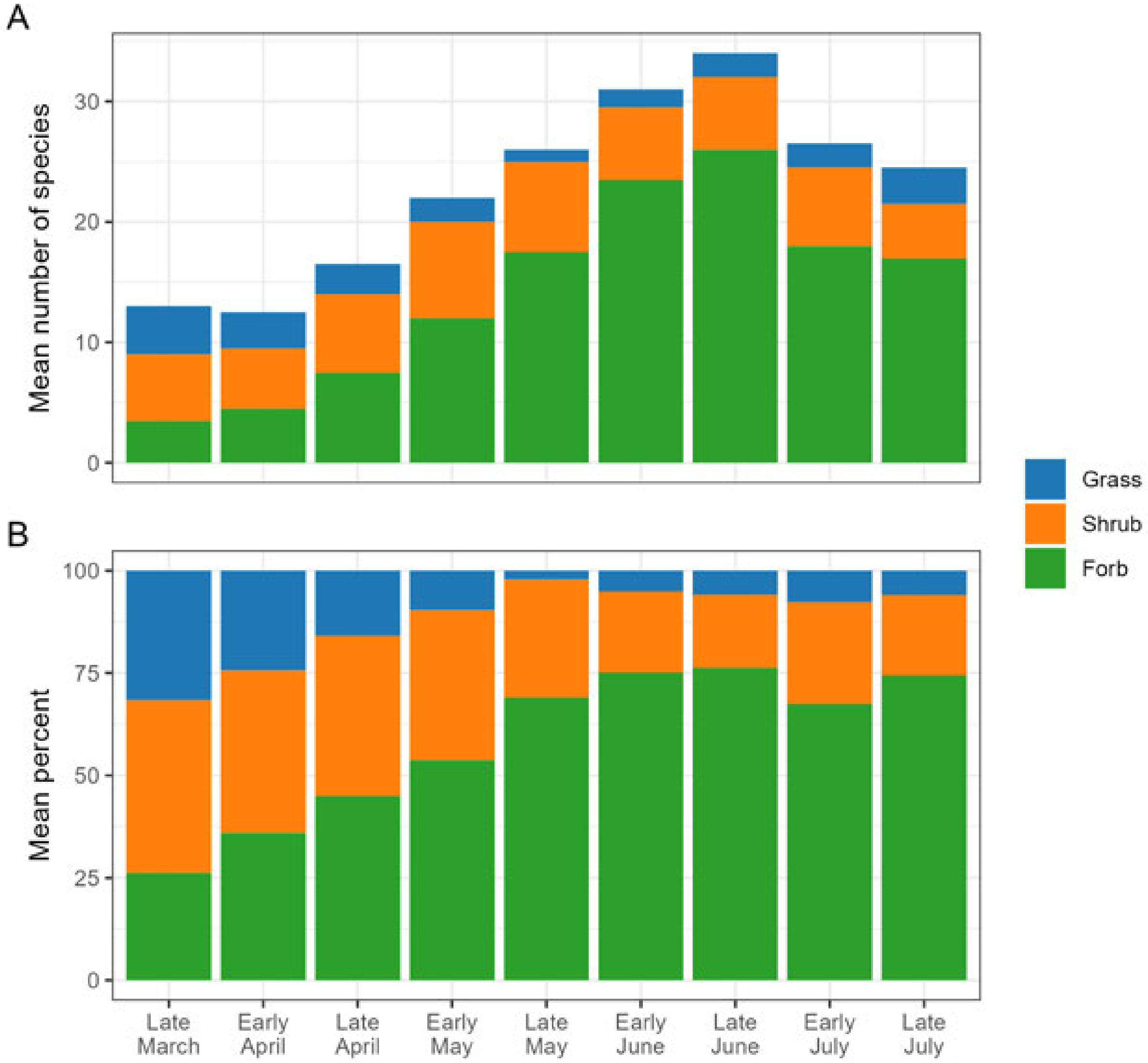


Figure 116. Mean number of species by growth form (panel A) and mean percent of each growth form in each summer sampling period across years 2020 and 2021 for fecal samples analyzed using DNA metabarcoding.

From the DNA metabarcoding of 16 fecal composite samples from winter, we identified 136 species in 78 genera as forage species, including 74 forb, 24 shrub, and 23 grass species (Table 17, Figure 117). The number of forage species varied by study area, with the fewest number of species occurring in Garfield-Rosebud (n = 29 species) and Powder River-Carter (n = 30 species) and the greatest number of species occurring in Madison (n = 65 species) and Paradise (n = 64 species; Table 18, Figure 118).

Table 17. The number and percent of composite samples across all 8 study areas (total of 16 composite samples) with a detection of each winter forage species/item.

Taxon	Growth form	No. of samples detected	Percent
Artemisia cana	Shrub	16	100.0
Artemisia sp.	Shrub	16	100.0
Asteraceae sp.	Unknown	16	100.0
Phlox sp.	Forb	13	81.3
Ericameria sp.	Shrub	12	75.0
Poa nemoralis	Graminoid	12	75.0
Atriplex patula	Shrub	11	68.8
Bromus sp.	Graminoid	11	68.8
Atriplex sp.	Shrub	10	62.5
Eriogonum sp.	Forb	10	62.5
Poa sp.	Graminoid	10	62.5
Sphaeralcea coccinea	Forb	10	62.5
Opuntia fragilis	Forb	9	56.3
Artemisia nova	Shrub	8	50.0
Gutierrezia sp.	Shrub	8	50.0
Juniperus communis	Shrub	8	50.0
Phlox hoodii	Forb	8	50.0
Antennaria sp.	Forb	7	43.8
Bromus tectorum	Graminoid	7	43.8
Krascheninnikovia lanata	Shrub	7	43.8
Chrysothamnus sp.	Shrub	6	37.5
Pinus sp.	Tree	6	37.5
Sarcobatus vermiculatus	Shrub	6	37.5
Selaginella sp.	Moss	6	37.5
Brassicaceae sp.	Forb	5	31.3
Bromus secalinus	Graminoid	5	31.3
Carex sp.	Graminoid	5	31.3
Juniperus sp.	Shrub	5	31.3
Poa pratensis	Graminoid	5	31.3
Poaceae sp.	Graminoid	5	31.3
Sphaeralcea sp.	Forb	5	31.3
Symphyotrichum sp.	Forb	5	31.3
Alyssum alyssoides	Forb	4	25.0
Artemisia frigida	Shrub	4	25.0
Heterotheca sp.	Forb	4	25.0
Oocystaceae sp.	Algae	4	25.0
Packera sp.	Forb	4	25.0
Suaeda sp.	Forb	4	25.0
Bassia scoparia	Forb	3	18.8
Centaurea sp.	Forb	3	18.8
Centaurea stoebe	Forb	3	18.8
Cerastium sp.	Forb	3	18.8
Cirsium arvense	Forb	3	18.8
Lolium sp.	Graminoid	3	18.8
Oenothera sp.	Forb	3	18.8
Phytolaccaceae sp.	Forb	3	18.8
Picea sp.	Tree	3	18.8
Pinaceae sp.	Tree	3	18.8
Rosa sp.	Shrub	3	18.8
Sisymbrium altissimum	Forb	3	18.8
Solidago sp.	Forb	3	18.8
Triticum aestivum	Graminoid	3	18.8
Triticum sp.	Graminoid	3	18.8
Artemisia tridentata	Shrub	2	12.5
Astragalus gilviflorus	Forb	2	12.5
Astragalus sp.	Forb	2	12.5

Taxon	Growth form	No. of samples detected	Percent
Boraginaceae sp.	Forb	2	12.5
Carex duriuscula	Graminoid	2	12.5
Cerastium beeringianum	Forb	2	12.5
Chenopodiaceae sp.	Unknown	2	12.5
Comandra umbellata	Forb	2	12.5
Cryptantha flavoculata	Forb	2	12.5
Cynoglossum officinale	Forb	2	12.5
Eriogonum pauciflorum	Forb	2	12.5
Festuca sp.	Graminoid	2	12.5
Glycyrrhiza lepidota	Forb	2	12.5
Hordeum sp.	Graminoid	2	12.5
Iva sp.	Forb	2	12.5
Lactuca sp.	Forb	2	12.5
Medicago lupulina	Forb	2	12.5
Medicago sp.	Forb	2	12.5
Oxytropis sp.	Forb	2	12.5
Polytrichaceae sp.	Moss	2	12.5
Prunus virginiana	Shrub	2	12.5
Salsola sp.	Forb	2	12.5
Sphaeralcea munroana	Forb	2	12.5
Actinidiaceae sp.	Shrub	1	6.3
Aegilops sp.	Graminoid	1	6.3
Allium sp.	Forb	1	6.3
Alopecurus aequalis	Graminoid	1	6.3
Alyssum sp.	Forb	1	6.3
Ambrosia artemisiifolia	Forb	1	6.3
Ambrosia sp.	Forb	1	6.3
Anacardiaceae sp.	Shrub	1	6.3
Antennaria rosea	Forb	1	6.3
Artemisia rigida	Shrub	1	6.3
Astragalus argophyllus	Forb	1	6.3
Astragalus missouriensis	Forb	1	6.3
Bassia sp.	Forb	1	6.3
Brassica oleracea	Forb	1	6.3
Brassica rapa	Forb	1	6.3
Brassica sp.	Forb	1	6.3
Caryophyllales sp.	Unknown	1	6.3
Catabrosa aquatica	Graminoid	1	6.3
Chlorellaceae sp.	Algae	1	6.3
Dalea purpurea	Forb	1	6.3
Descurainia sophia	Forb	1	6.3
Descurainia sp.	Forb	1	6.3
Erigeron sp.	Forb	1	6.3
Euphorbiaceae sp.	Forb	1	6.3
Fabaceae sp.	Unknown	1	6.3
Festuca idahoensis	Graminoid	1	6.3
Glyceria striata	Graminoid	1	6.3
Hedysarum sp.	Forb	1	6.3
Helianthus sp.	Forb	1	6.3
Helianthus tuberosus	Forb	1	6.3
Iva axillaris	Forb	1	6.3
Juncus articulatus	Graminoid	1	6.3
Klebsormidiaceae sp.	Algae	1	6.3
Koeleria sp.	Graminoid	1	6.3
Liatris sp.	Forb	1	6.3
Linanthus pungens	Forb	1	6.3
Linaria vulgaris	Forb	1	6.3
Linum sp.	Forb	1	6.3

Taxon	Growth form	No. of samples detected	Percent
Lithospermum incisum	Forb	1	6.3
Lithospermum sp.	Forb	1	6.3
Lupinus sp.	Forb	1	6.3
Medicago sativa	Forb	1	6.3
Phlox alyssifolia	Forb	1	6.3
Poales sp.	Graminoid	1	6.3
Populus deltoides	Tree	1	6.3
Prunus padus	Shrub	1	6.3
Prunus sp.	Shrub	1	6.3
Pseudotsuga menziesii	Tree	1	6.3
Rhus sp.	Shrub	1	6.3
Rubiaceae sp.	Unknown	1	6.3
Rumex acetosella	Forb	1	6.3
Salix sp.	Shrub	1	6.3
Solanaceae sp.	Forb	1	6.3
Taraxacum sp.	Forb	1	6.3
Tetradymia canescens	Shrub	1	6.3
Tetraneuris acaulis	Forb	1	6.3
Tragopogon dubius	Forb	1	6.3
Tragopogon pratensis	Forb	1	6.3
Trisetum sp.	Graminoid	1	6.3
Verbena sp.	Forb	1	6.3

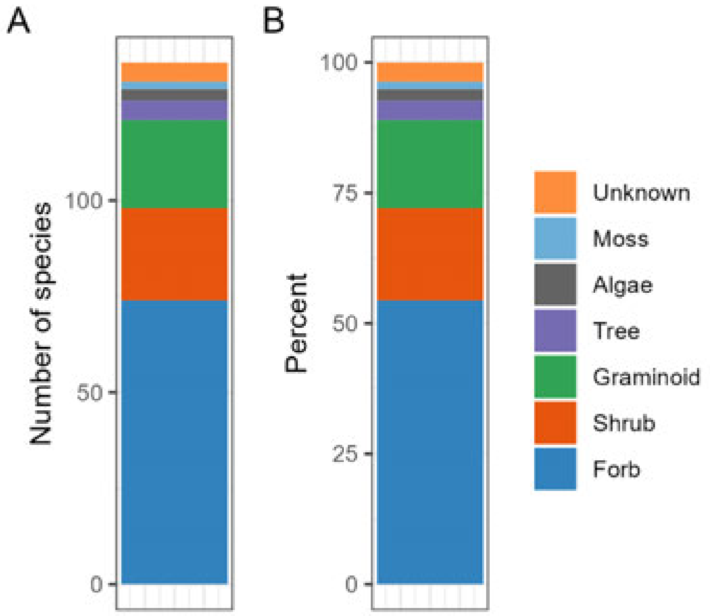


Figure 117. The number (A) and percent (B) of winter forage species/items in each growth form class across study areas.

Table 18. The number and percent of composite samples within each study area (total of 2 composite samples per study area) with a detection of each winter forage species/item.

Study area	Taxon	Growth form	No. of samples detected	Percent
Big Hole	Artemisia cana	Shrub	2	100
	Artemisia nova	Shrub	2	100
	Artemisia sp.	Shrub	2	100
	Asteraceae sp.	Unknown	2	100
	Chrysothamnus sp.	Shrub	2	100
	Ericameria sp.	Shrub	2	100
	Eriogonum sp.	Forb	2	100
	Phlox hoodii	Forb	2	100
	Phlox sp.	Forb	2	100
	Poa nemoralis	Graminoid	2	100
	Sarcobatus vermiculatus	Shrub	2	100
	Solidago sp.	Forb	2	100
	Sphaeralcea coccinea	Forb	2	100
	Allium sp.	Forb	1	50
	Astragalus sp.	Forb	1	50
	Bassia scoparia	Forb	1	50
	Boraginaceae sp.	Forb	1	50
	Brassica oleracea	Forb	1	50
	Brassica sp.	Forb	1	50
	Chenopodiaceae sp.	Unknown	1	50
	Cirsium arvense	Forb	1	50
	Glycyrrhiza lepidota	Forb	1	50
	Iva axillaris	Forb	1	50
	Iva sp.	Forb	1	50
	Krascheninnikovia lanata	Shrub	1	50
	Linanthus pungens	Forb	1	50
	Linum sp.	Forb	1	50
	Phytolaccaceae sp.	Forb	1	50
	Pinaceae sp.	Tree	1	50
	Poa pratensis	Graminoid	1	50
	Poaceae sp.	Graminoid	1	50
	Pseudotsuga menziesii	Tree	1	50
	Solanaceae sp.	Forb	1	50
	Sphaeralcea sp.	Forb	1	50
Madison	Artemisia cana	Shrub	2	100
	Artemisia sp.	Shrub	2	100
	Asteraceae sp.	Unknown	2	100
	Bromus sp.	Graminoid	2	100
	Chrysothamnus sp.	Shrub	2	100
	Ericameria sp.	Shrub	2	100
	Festuca sp.	Graminoid	2	100
	Gutierrezia sp.	Shrub	2	100
	Juniperus communis	Shrub	2	100
	Medicago sp.	Forb	2	100
	Packera sp.	Forb	2	100
	Phlox hoodii	Forb	2	100
	Phlox sp.	Forb	2	100
	Poa nemoralis	Graminoid	2	100
	Poa sp.	Graminoid	2	100
	Rosa sp.	Shrub	2	100
	Selaginella sp.	Moss	2	100
	Sphaeralcea coccinea	Forb	2	100
	Sphaeralcea sp.	Forb	2	100
	Symphyotrichum sp.	Forb	2	100
	Alyssum alyssoides	Forb	1	50
	Antennaria rosea	Forb	1	50
	Antennaria sp.	Forb	1	50
	Artemisia frigida	Shrub	1	50

Study area	Taxon	Growth form	No. of samples detected	Percent
	Astragalus gilviflorus	Forb	1	50
	Brassica rapa	Forb	1	50
	Brassicaceae sp.	Forb	1	50
	Bromus tectorum	Graminoid	1	50
	Carex sp.	Graminoid	1	50
	Centaurea sp.	Forb	1	50
	Centaurea stoebe	Forb	1	50
	Cirsium arvense	Forb	1	50
	Comandra umbellata	Forb	1	50
	Cynoglossum officinale	Forb	1	50
	Descurainia sophia	Forb	1	50
	Descurainia sp.	Forb	1	50
	Erigeron sp.	Forb	1	50
	Eriogonum sp.	Forb	1	50
	Euphorbiaceae sp.	Forb	1	50
	Heterotheca sp.	Forb	1	50
	Juniperus sp.	Shrub	1	50
	Lactuca sp.	Forb	1	50
	Linaria vulgaris	Forb	1	50
	Lithospermum incisum	Forb	1	50
	Lithospermum sp.	Forb	1	50
	Lolium sp.	Graminoid	1	50
	Lupinus sp.	Forb	1	50
	Medicago sativa	Forb	1	50
	Oenothera sp.	Forb	1	50
	Oocystaceae sp.	Algae	1	50
	Oxytropis sp.	Forb	1	50
	Picea sp.	Tree	1	50
	Pinaceae sp.	Tree	1	50
	Pinus sp.	Tree	1	50
	Poa pratensis	Graminoid	1	50
	Poaceae sp.	Graminoid	1	50
	Prunus padus	Shrub	1	50
	Prunus virginiana	Shrub	1	50
	Salix sp.	Shrub	1	50
	Sisymbrium altissimum	Forb	1	50
	Solidago sp.	Forb	1	50
	Sphaeralcea munroana	Forb	1	50
	Taraxacum sp.	Forb	1	50
	Tetradymia canescens	Shrub	1	50
	Verbena sp.	Forb	1	50
Paradise	Antennaria sp.	Forb	2	100
	Artemisia cana	Shrub	2	100
	Artemisia sp.	Shrub	2	100
	Asteraceae sp.	Unknown	2	100
	Bromus sp.	Graminoid	2	100
	Carex sp.	Graminoid	2	100
	Centaurea sp.	Forb	2	100
	Centaurea stoebe	Forb	2	100
	Chrysothamnus sp.	Shrub	2	100
	Cryptantha flavoculata	Forb	2	100
	Ericameria sp.	Shrub	2	100
	Eriogonum sp.	Forb	2	100
	Gutierrezia sp.	Shrub	2	100
	Heterotheca sp.	Forb	2	100
	Juniperus communis	Shrub	2	100
	Juniperus sp.	Shrub	2	100
	Krascheninnikovia lanata	Shrub	2	100
	Lolium sp.	Graminoid	2	100
	Packera sp.	Forb	2	100
	Phlox hoodii	Forb	2	100

Study area	Taxon	Growth form	No. of samples detected	Percent
	Phlox sp.	Forb	2	100
	Pinus sp.	Tree	2	100
	Poa nemoralis	Graminoid	2	100
	Poa pratensis	Graminoid	2	100
	Poa sp.	Graminoid	2	100
	Salsola sp.	Forb	2	100
	Selaginella sp.	Moss	2	100
	Sisymbrium altissimum	Forb	2	100
	Alyssum alyssoides	Forb	1	50
	Anacardiaceae sp.	Shrub	1	50
	Artemisia frigida	Shrub	1	50
	Astragalus argophyllus	Forb	1	50
	Astragalus gilviflorus	Forb	1	50
	Astragalus missouriensis	Forb	1	50
	Astragalus sp.	Forb	1	50
	Atriplex patula	Shrub	1	50
	Bassia scoparia	Forb	1	50
	Bassia sp.	Forb	1	50
	Boraginaceae sp.	Forb	1	50
	Brassicaceae sp.	Forb	1	50
	Bromus tectorum	Graminoid	1	50
	Carex duriuscula	Graminoid	1	50
	Catabrosa aquatica	Graminoid	1	50
	Comandra umbellata	Forb	1	50
	Cynoglossum officinale	Forb	1	50
	Festuca idahoensis	Graminoid	1	50
	Glyceria striata	Graminoid	1	50
	Hedysarum sp.	Forb	1	50
	Juncus articulatus	Graminoid	1	50
	Koeleria sp.	Graminoid	1	50
	Liatris sp.	Forb	1	50
	Medicago lupulina	Forb	1	50
	Oocystaceae sp.	Algae	1	50
	Oxytropis sp.	Forb	1	50
	Phlox alyssifolia	Forb	1	50
	Populus deltoides	Tree	1	50
	Prunus sp.	Shrub	1	50
	Prunus virginiana	Shrub	1	50
	Rhus sp.	Shrub	1	50
	Rosa sp.	Shrub	1	50
	Sarcobatus vermiculatus	Shrub	1	50
	Sphaeralcea coccinea	Forb	1	50
	Sphaeralcea sp.	Forb	1	50
	Trisetum sp.	Graminoid	1	50
Musselshell	Artemisia cana	Shrub	2	100
	Artemisia sp.	Shrub	2	100
	Asteraceae sp.	Unknown	2	100
	Atriplex patula	Shrub	2	100
	Atriplex sp.	Shrub	2	100
	Krascheninnikovia lanata	Shrub	2	100
	Oenothera sp.	Forb	2	100
	Opuntia fragilis	Forb	2	100
	Phlox sp.	Forb	2	100
	Poa nemoralis	Graminoid	2	100
	Suaeda sp.	Forb	2	100
	Alyssum alyssoides	Forb	1	50
	Artemisia frigida	Shrub	1	50
	Artemisia nova	Shrub	1	50
	Artemisia tridentata	Shrub	1	50
	Brassicaceae sp.	Forb	1	50
	Bromus secalinus	Graminoid	1	50

Study area	Taxon	Growth form	No. of samples detected	Percent
	Bromus sp.	Graminoid	1	50
	Cerastium beeringianum	Forb	1	50
	Cerastium sp.	Forb	1	50
	Ericameria sp.	Shrub	1	50
	Eriogonum sp.	Forb	1	50
	Gutierrezia sp.	Shrub	1	50
	Heterotheca sp.	Forb	1	50
	Iva sp.	Forb	1	50
	Juniperus communis	Shrub	1	50
	Juniperus sp.	Shrub	1	50
	Lactuca sp.	Forb	1	50
	Phytolaccaceae sp.	Forb	1	50
	Picea sp.	Tree	1	50
	Poa sp.	Graminoid	1	50
	Rumex acetosella	Forb	1	50
	Sarcobatus vermiculatus	Shrub	1	50
	Sphaeralcea coccinea	Forb	1	50
	Sphaeralcea munroana	Forb	1	50
	Symphyotrichum sp.	Forb	1	50
	Tetraneuris acaulis	Forb	1	50
Fergus-Petroleum	Antennaria sp.	Forb	2	100
	Artemisia cana	Shrub	2	100
	Artemisia sp.	Shrub	2	100
	Asteraceae sp.	Unknown	2	100
	Atriplex patula	Shrub	2	100
	Atriplex sp.	Shrub	2	100
	Bromus sp.	Graminoid	2	100
	Bromus tectorum	Graminoid	2	100
	Juniperus communis	Shrub	2	100
	Opuntia fragilis	Forb	2	100
	Sarcobatus vermiculatus	Shrub	2	100
	Artemisia nova	Shrub	1	50
	Bromus secalinus	Graminoid	1	50
	Carex sp.	Graminoid	1	50
	Caryophyllales sp.	Unknown	1	50
	Cerastium beeringianum	Forb	1	50
	Cerastium sp.	Forb	1	50
	Chlorellaceae sp.	Algae	1	50
	Cirsium arvense	Forb	1	50
	Ericameria sp.	Shrub	1	50
	Helianthus sp.	Forb	1	50
	Helianthus tuberosus	Forb	1	50
	Oocystaceae sp.	Algae	1	50
	Phlox sp.	Forb	1	50
	Phytolaccaceae sp.	Forb	1	50
	Poa nemoralis	Graminoid	1	50
	Poa pratensis	Graminoid	1	50
	Poa sp.	Graminoid	1	50
	Poaceae sp.	Graminoid	1	50
	Poales sp.	Graminoid	1	50
	Suaeda sp.	Forb	1	50
	Triticum aestivum	Graminoid	1	50
	Triticum sp.	Graminoid	1	50
South Philips	Artemisia cana	Shrub	2	100
	Artemisia nova	Shrub	2	100
	Artemisia sp.	Shrub	2	100
	Asteraceae sp.	Unknown	2	100
	Atriplex patula	Shrub	2	100
	Atriplex sp.	Shrub	2	100
	Bromus sp.	Graminoid	2	100
	Ericameria sp.	Shrub	2	100

Study area	Taxon	Growth form	No. of samples detected	Percent
	Sphaeralcea coccinea	Forb	2	100
	Triticum aestivum	Graminoid	2	100
	Triticum sp.	Graminoid	2	100
	Actinidiaceae sp.	Shrub	1	50
	Aegilops sp.	Graminoid	1	50
	Antennaria sp.	Forb	1	50
	Artemisia frigida	Shrub	1	50
	Artemisia tridentata	Shrub	1	50
	Bassia scoparia	Forb	1	50
	Brassicaceae sp.	Forb	1	50
	Bromus secalinus	Graminoid	1	50
	Bromus tectorum	Graminoid	1	50
	Carex duriuscula	Graminoid	1	50
	Carex sp.	Graminoid	1	50
	Eriogonum sp.	Forb	1	50
	Glycyrrhiza lepidota	Forb	1	50
	Gutierrezia sp.	Shrub	1	50
	Hordeum sp.	Graminoid	1	50
	Klebsormidiaceae sp.	Algae	1	50
	Krascheninnikovia lanata	Shrub	1	50
	Opuntia fragilis	Forb	1	50
	Phlox sp.	Forb	1	50
	Pinus sp.	Tree	1	50
	Poa nemoralis	Graminoid	1	50
	Poa sp.	Graminoid	1	50
	Poaceae sp.	Graminoid	1	50
	Polytrichaceae sp.	Moss	1	50
	Rubiaceae sp.	Unknown	1	50
	Selaginella sp.	Moss	1	50
	Sphaeralcea sp.	Forb	1	50
	Symphyotrichum sp.	Forb	1	50
Garfield-Rosebud	Artemisia cana	Shrub	2	100
	Artemisia sp.	Shrub	2	100
	Asteraceae sp.	Unknown	2	100
	Atriplex patula	Shrub	2	100
	Atriplex sp.	Shrub	2	100
	Bromus secalinus	Graminoid	2	100
	Bromus sp.	Graminoid	2	100
	Bromus tectorum	Graminoid	2	100
	Opuntia fragilis	Forb	2	100
	Phlox hoodii	Forb	2	100
	Phlox sp.	Forb	2	100
	Sphaeralcea coccinea	Forb	2	100
	Alopecurus aequalis	Graminoid	1	50
	Alyssum alyssoides	Forb	1	50
	Alyssum sp.	Forb	1	50
	Artemisia rigida	Shrub	1	50
	Brassicaceae sp.	Forb	1	50
	Eriogonum sp.	Forb	1	50
	Gutierrezia sp.	Shrub	1	50
	Juniperus communis	Shrub	1	50
	Juniperus sp.	Shrub	1	50
	Krascheninnikovia lanata	Shrub	1	50
	Pinus sp.	Tree	1	50
	Poa nemoralis	Graminoid	1	50
	Poa sp.	Graminoid	1	50
	Poaceae sp.	Graminoid	1	50
	Suaeda sp.	Forb	1	50
	Tragopogon dubius	Forb	1	50
	Tragopogon pratensis	Forb	1	50
Powder River-Carter	Artemisia cana	Shrub	2	100

Study area	Taxon	Growth form	No. of samples detected	Percent
	Artemisia nova	Shrub	2	100
	Artemisia sp.	Shrub	2	100
	Asteraceae sp.	Unknown	2	100
	Atriplex patula	Shrub	2	100
	Atriplex sp.	Shrub	2	100
	Ericameria sp.	Shrub	2	100
	Eriogonum pauciflorum	Forb	2	100
	Eriogonum sp.	Forb	2	100
	Opuntia fragilis	Forb	2	100
	Poa sp.	Graminoid	2	100
	Ambrosia artemisiifolia	Forb	1	50
	Ambrosia sp.	Forb	1	50
	Antennaria sp.	Forb	1	50
	Cerastium sp.	Forb	1	50
	Chenopodiaceae sp.	Unknown	1	50
	Dalea purpurea	Forb	1	50
	Fabaceae sp.	Unknown	1	50
	Gutierrezia sp.	Shrub	1	50
	Hordeum sp.	Graminoid	1	50
	Medicago lupulina	Forb	1	50
	Oocystaceae sp.	Algae	1	50
	Phlox sp.	Forb	1	50
	Picea sp.	Tree	1	50
	Pinaceae sp.	Tree	1	50
	Pinus sp.	Tree	1	50
	Poa nemoralis	Graminoid	1	50
	Polytrichaceae sp.	Moss	1	50
	Selaginella sp.	Moss	1	50
	Symphyotrichum sp.	Forb	1	50

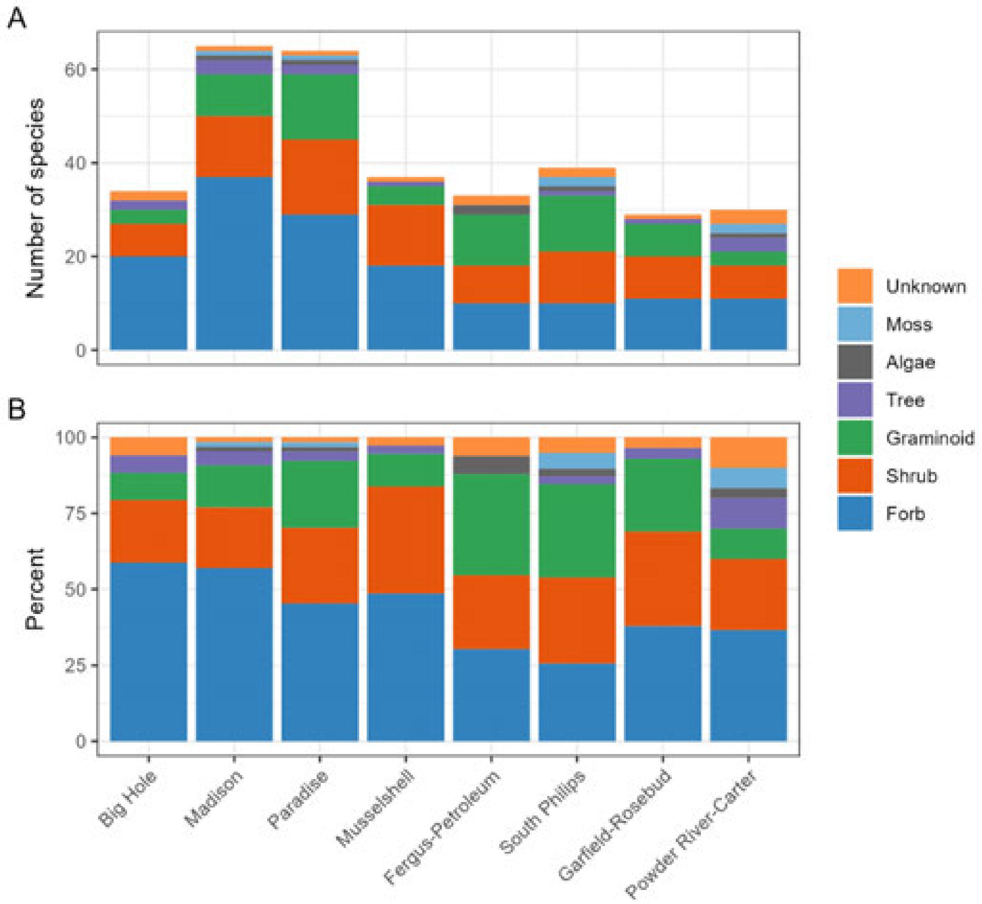


Figure 118. The number (A) and percent (B) of winter forage species/items in each growth form class within each study area.

Forb forage quality, estimated as digestible energy (in kilocalories per gram), averaged 3.5 ± 0.9 kcal/g (±SD) across all available (i.e., excluding 'used') sampling sites and varied across sampling sites in different land cover classes (Figure 119). Forb forage quality was highest in both grassland ($\bar{x}$ = 3.6, SD = 0.6) and shrubland ($\bar{x}$ = 3.6, SD = 0.7) and lowest in agriculture ($\bar{x}$ = 3.0, SD = 1.6), averaged across summer sampling periods. Generally, forb forage quality declined through summer across and within all land cover types, with the highest values estimated during early May ($\bar{x}$ = 3.8, SD = 0.3) and lowest during late July ($\bar{x}$ = 3.1, SD = 0.4). In agriculture, forb forage quality averaged highest during early May ($\bar{x}$ = 3.9, SD = 0.1) and lowest during late April ($\bar{x}$ = 1.8, SD = 2.0). In grassland, forb forage quality averaged highest during early April ($\bar{x}$ = 3.7, SD = 1.0) and lowest during late July ($\bar{x}$ = 3.1, SD = 0.2). In shrubland, forb forage quality averaged highest during late April ($\bar{x}$ = 3.9, SD = 0.6) and lowest during early July ($\bar{x}$ = 3.2, SD = 0.4). We did not summarize forb forage quality for forest cover types due to lack of sufficient data.

Shrub forage quality, estimated as digestible energy (in kilocalories per gram), averaged 2.7 ± 1.7 kcal/g (±SD) across all available (i.e., excluding 'used') sampling sites and varied across sampling sites in different land cover classes (Figure 119). Shrub forage quality was highest in shrubland ($\bar{x}$ = 3.8, SD = 0.4) and lowest in grassland ($\bar{x}$ = 2.4, SD = 1.8), averaged across summer sampling periods. Generally, shrub forage quality declined throughout summer, with the highest values estimated during late March ($\bar{x}$ = 3.6, SD = 1.3) and lowest during late June ($\bar{x}$ = 2.3, SD = 1.8). In grasslands, shrub forage quality averaged highest during late July ($\bar{x}$ = 3.4, SD = 0.4) and lowest during late June ($\bar{x}$ = 1.8, SD = 1.8). In shrubland, shrub forage quality averaged highest during late March ($\bar{x}$ = 4.1, SD = 0.4) and lowest during early July ($\bar{x}$ = 3.3, SD = 0.3). We did not summarize shrub forage quality for agriculture or forest cover types due to lack of sufficient data.

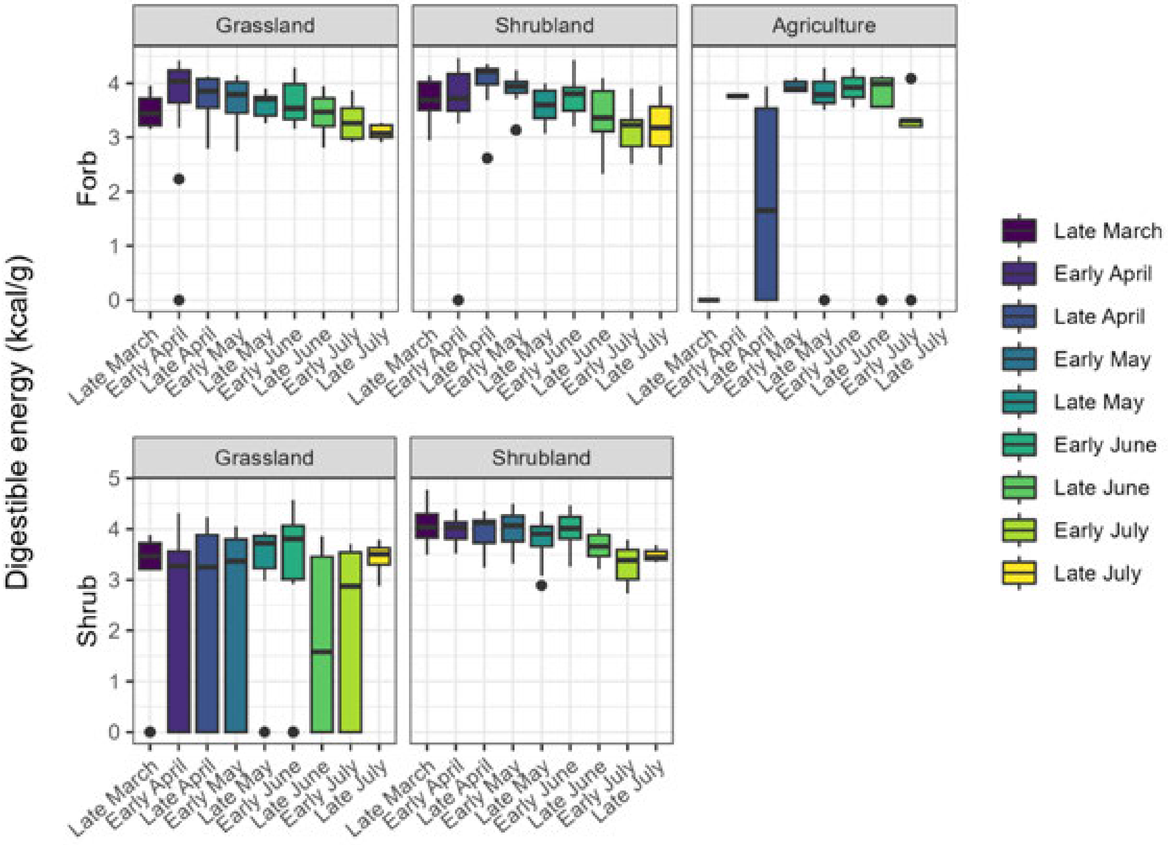


Figure 119. Summer digestible energy (i.e., forage quality; kilocalories per gram) of forbs (top 4 panels) and shrubs (bottom 2 panels) measured in each landcover type and sampling period. Data is summarized across 'available' sampling sites only (i.e., excluding 'used' sites). We removed panels for forest land cover type for forbs and agriculture and forest landcover types for shrubs due to lack of data. Horizontal lines through boxes represent median values, the length of the box represents the middle 50% of observations (IQR), vertical lines represent observations within 1.5x the range of the IQR, and points outside the vertical lines represent observations >1.5x the range of the IQR.

The most supported summer resource selection model indicated the covariates representing emergent forage cover and bare ground cover were potentially important in pronghorn resource selection. Pronghorn selection was correlated with higher emergent forage cover (Figure 120A). There was a quadratic relationship between relative probability of selection and percent cover of bare ground, with selection for bare ground peaking at 70% bare ground cover and declined at higher and lower levels of bare ground (Figure 120B). This peak in selection occurred below the median value of bare ground cover observed at available sampling sites (77.5%, interquartile range: 63.9–86.5%).

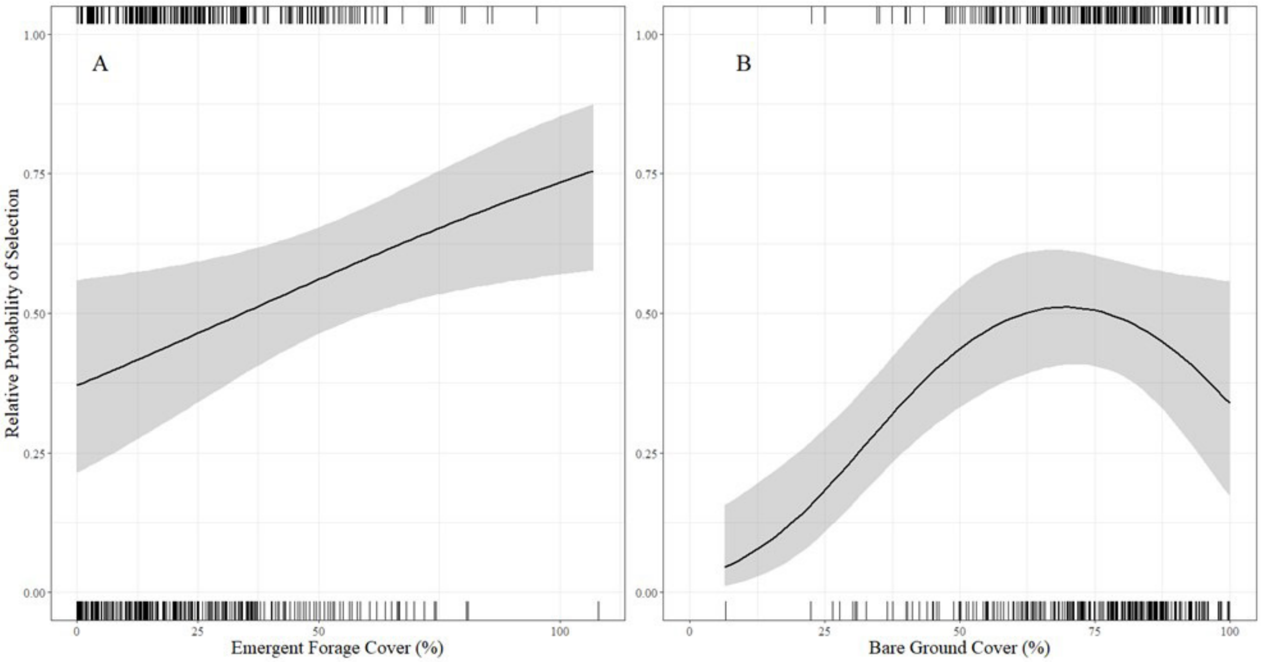


Figure 120. Predictive relationship of relative probability of selection (black line) and 95% confidence interval (shaded gray) across the range of observed values of (A) percent cover of emergent forage and (B) percent cover of bare ground estimated by holding all other covariates constant at their mean and using the final summer resource selection model for female pronghorn in central Montana, 2021–2022. The distributions of covariate values of used and available sites are represented by the upper and lower rug, respectively. Reproduced from Crane et al. (in preparation).

The time-varying resource selection model indicated that pronghorn selection of forage cover, forb DE, and shrub cover varied during the summer (Figure 121). Pronghorn selection showed a significant positive correlation with forage cover briefly during the early part of the season (49-32 days before peak spring) but was not significantly associated with forage cover during the remainder of the summer (Figure 121B). Although initially showing an avoidance of forb digestible energy, pronghorn selection of forb DE increased during the beginning of the season, until selection for forb DE peaked just prior to the peak of spring conditions. Pronghorn selected for shrub cover during the early parts of the season, with selection strength slightly increasing during and immediately following the fawning period. During late summer, pronghorn exhibited avoidance of shrub cover.

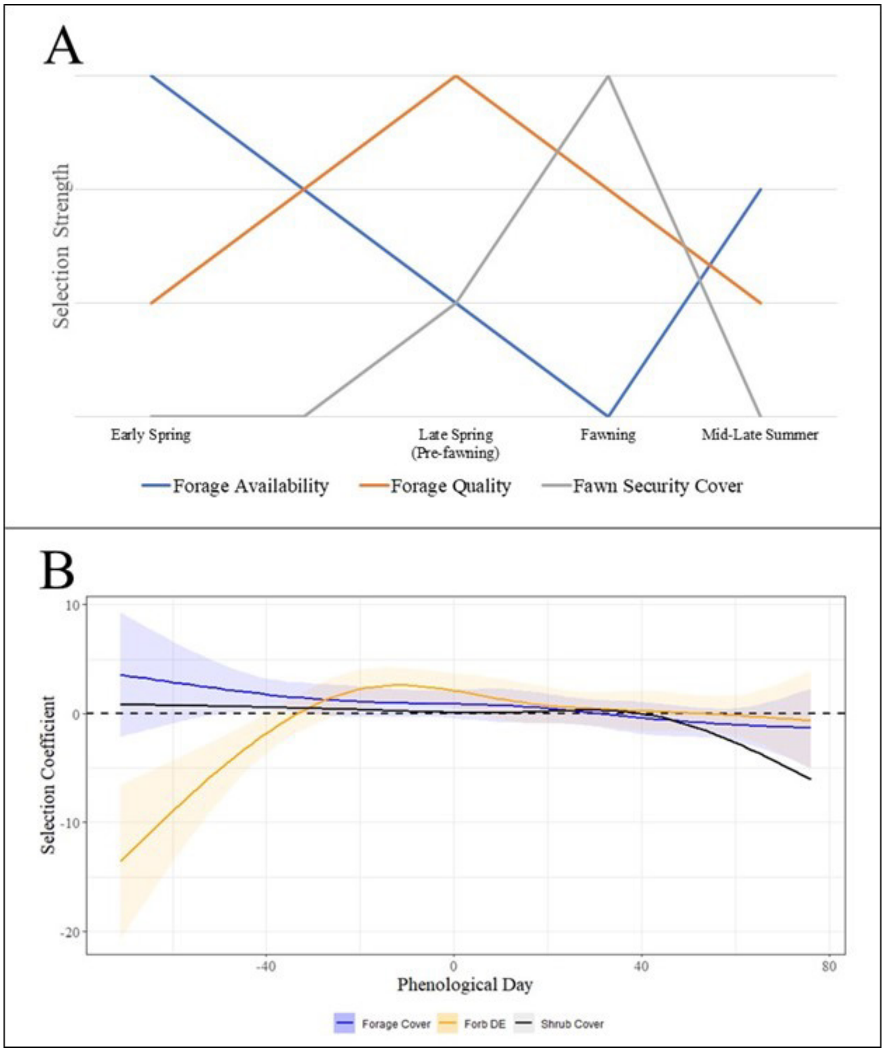


Figure 121. Plots of time-varying resource selection of female pronghorn during the summer in central Montana, USA, 2021–2022. Panel A depicts predicted temporal variation in resource selection. Panel B shows the selection coefficients (solid lines) and corresponding 95% confidence intervals (shaded area) of each covariate with a temporal interaction term in the time-varying resource selection global model. Phenological day represents number of days until (negative values) or after (positive values) 'peak spring' each year. Coefficient estimates >0 (dashed line) indicate a positive relationship with that covariate during the given time, whereas values <0 indicate a negative relationship. Shrub cover was evaluated using the quadratic functional form, while forage cover and forb DE were evaluated using the linear functional form, with each interacted with a natural cubic spline function of time with four degrees of freedom. Reproduced from Crane et al. (in preparation).

Discussion

Resource selection by pronghorn during the summer in central Montana correlated with forage quality (i.e., emergent forage cover, forb DE) and fawn security (i.e., bare ground cover, shrub cover). Forage availability (i.e., forage species cover and biomass of forbs and shrubs) and anthropogenic features (i.e., roads and fences) did not correlate with pronghorn resource selection in the summer, which contrasts with other studies reporting that pronghorn avoid these features (Jones et al. 2019, 2022, Reinking et al. 2019, Opatz et al. 2023). Further, the time-varying model suggested pronghorn selection for forb digestible energy varied temporally, with the peak in selection for forb digestible energy occurring during the last month of gestation for pronghorn (i.e., late April – early May), which is nutritionally demanding. As such, we conclude that observed pronghorn selection of forage quality aligned with changing vegetation resources and biological needs associated with late gestation nutrition.

Female pronghorn also appeared to select resources to meet fawn security needs. Our summer resource selection model indicated that pronghorn selected for areas with less bare ground cover than generally available but appeared to avoid areas with lower amounts of bare ground cover (which were predicted to provide greater cover for fawns). Our time-varying resource selection model indicated a slight increase in selection for shrub cover during the fawning period, this selection rapidly decreased, and pronghorn selected strongly against shrub cover during the late summer. Our results may indicate that female pronghorn must balance between fawn security cover and predation risk, as areas with more shrub cover and less bare ground cover may provide hiding cover for fawns, as well as provide predators with more stalking cover (Bodie 1978, Yoakum 2004*c*). Our study suggests pronghorn may be balancing these risks through their selection of resources (i.e., by selecting areas with only slightly less bare ground than available) and varying their selection for shrub cover during the summer to avoid shrub cover once fawns become reliant on early detection to avoid predation.

Management Implications

Management actions affecting forage quality and fawn security cover will likely have the greatest influence on pronghorn resource selection. Habitat improvement strategies focused on providing a consistent availability of highly nutritious forbs and newly emergent forage species will likely have the greatest influence on pronghorn resource selection. Since pronghorn selection for fawn security cover varied significantly during the summer, managers should consider a mosaic approach to managing shrub cover, and provide a landscape containing areas with heavy, moderate, and minimal shrub cover.

Conclusions & management recommendations

Key Findings

- Across 8 study areas occurring in southwest, central, and southeast Montana, we GPS-collared and monitored 702 adult female pronghorn, of which 373 (53%) died and 64 (9%) had malfunctioning collars during the study (Madison study area: Jan 2019 – Jun 2023, all other study areas: Jan 2020 – Jun 2023). *(Capture, instrumentation, & sampling)*

- The majority of mortalities were classified as unknown (36%), with the remaining attributed to predation (23%), natural (18%), harvest (12%), capture (9%), vehicle collision (1%), train collision (<1%), and incidental snaring (<1%). Mortalities varied by study area. *(Survival monitoring & analysis)*

- Estimated monthly survival probabilities averaged 0.94 (ranging 0.76 – 0.97), with estimates for summer months (Jul – Aug) averaging slightly higher (0.948) as compared to fall (Sep – Nov; 0.938), winter (Dec – Mar; 0.942), and spring (Apr – Jun; 0.943) months. Estimated annual survival probabilities varied between 0.57 (CRI 0.43 - 0.71) and 0.81 (CRI 0.71 - 0.90); however, credible intervals overlapped substantially across most years within study areas and across all study areas. *(Survival monitoring & analysis)*

- Seasonal movement patterns of collared individuals were diverse within and across study areas. We mapped individual movement pathways, migration routes, and seasonal ranges for each study area, the majority of which had not previously been well-known or described. *(Objective 1.1: Seasonal ranges and migration routes)*

- Across all study areas and years, most animal-years (77%) did not depart their initial winter range during the summer, with over half of all animal-years (59%) remaining as residents, 11% exhibiting gradual range shifts (i.e., gradual movers), and 7% departing to new winter ranges during the fall (i.e., fall dispersers). The remainder of animal-years, comprising nearly a fourth of all animal-years (23%), departed their initial winter range and moved to summer range, with 65% of these returning to their initial winter range and 35% dispersing to a new winter range. Of those that returned to their initial winter range, we classified 79% as dual-range migrants, 18% as multi-range migrants, and 3% as commuter migrants. These proportions varied by year, with about a third of all individuals switching migratory strategies each year. *(Objective 1.2: Pronghorn migratory behaviors)*

- Migratory behaviors varied by study area, with individuals that did not distinctly depart their initial winter range during the summer (i.e., residents, gradual-movers, and fall dispersers) comprising the majority of animal-years in all study areas (ranging 62-69% in the Madison, 69-82% in South Philips, 73-88% in Paradise, 87-91% in Musselshell, 88-96% in Fergus-Petroleum, 88-95% in Powder River-Carter, and 93-94% in Garfield-Rosebud) except the Big Hole, which was comprised primarily of migrants (ranging 57-75%). *(Objective 1.2: Pronghorn migratory behaviors)*

- We developed an online fence mapping platform and mapped 48,694 km (30,257 mi) of fences from aerial imagery and ground-based visits. Of the 2,496 km (1,550 mi) fences visited and verified on the ground, we classified 2,062 km (1,281 mi; 82.6%) as barbed and 404 km (251 mi; 16.2%) as woven wire type. We used this fence data to produce a tool ranking and mapping fencing based on relative levels of altered fence encounters of collared pronghorn and to evaluate the effects of different fence types on pronghorn movement behaviors. *(Objective 3.1: Identification of potential barriers to movements)*

- Woven wire fences substantially reduced unaltered (i.e., "normal") initial and crossing responses and increased passage times of collared pronghorn 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 fence 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 14 hours. Pronghorn knowledge of and fidelity to specific permeable locations along fences likely allow some woven wire fences and most strand fences, regardless of the average lowest wire height, to be permeable. (*Objective 3.2: Effect of fence types on pronghorn movement behaviors*)

- On average, the 3 western hunting districts (encompassing Big Hole, Madison, and Paradise study areas) had decreasing pronghorn populations since 2015, while the eastern hunting districts had stable or increasing populations. Adult female survival was the most important vital rate influencing pronghorn population dynamics. Four-month recruitment was also positively associated with population growth, but this effect was relatively weak compared to adult female survival. Adult female survival ≥ 0.75 generally resulted in stable or increasing populations. Adult female survival <0.75 could still result in stable or increasing populations, if 4-month recruitment was >0.7. There was considerable uncertainty in the factors affecting vital rates across hunting districts; although there was some evidence that winter severity was negatively associated with adult survival and/or 4-month recruitment in some eastern hunting districts. (*Objective 4: Developing an integrated population model)*

- During the spring and summer growing season in central Montana, pronghorn selected for areas associated with increased forage quality measurements (emergent forage cover and forb digestible energy content) and fawn security (greater shrub cover and intermediate levels of bare ground cover). The peak in selection for forb digestible energy coincided with the last month of pronghorn gestation (i.e., late April – early May). Forb forage quality was highest in both grasslands and shrublands and generally declined through the summer with highest values in early May and lowest in late July. Selection for shrub cover slightly increased during the fawning period and then decreased to avoidance during the late summer, indicating pronghorn may be using shrub cover to hide their fawns and then avoiding shrub cover once fawns are more agile to avoid predation. (*Objective 5: Evaluating pronghorn resource selection)*

Management Recommendations

This study collected information on pronghorn movements and population dynamics that managers can use to help guide management decision-making. Across the study areas, we observed substantial variation in movement patterns and migration routes, the majority of which were not previously well-known or described, providing new insight into how pronghorn use the landscape (*Objective 1*). The movement information can be useful for informing habitat conservation and mitigation efforts, harvest and game damage management, and aerial survey methodologies. When considering habitat mitigation efforts related to fences, managers within the study areas can consider using the fence permeability tool to identify and prioritize modifying the fences with the highest movement barrier effect to collared pronghorn (*Objective 3.1*). Managers outside of the study areas, where no pronghorn collar data exists, can consider prioritizing the removal of woven wire fences, incorporating variation in the bottom strand height of strand wire fences, and/or implementing fence gate management plans to reduce the effect of fences to alter pronghorn movements (*Objective 3.2*, DeVoe et al. 2022). Additionally, an ongoing fence mapping effort in collaboration with BLM can provide managers with important information on the spatial distribution and physical characteristics (e.g., fence type, number of strands, bottom wire height) of fences found both within and outside of the study areas (*Objective 3.1*). Lastly, managers can consider management actions to provide consistently available high-quality forbs and newly emergent forage species and create a mosaic of low, moderate, and high shrub cover to improve pronghorn summer and fawning habitat (*Objective 5*).

Our results from the integrated population modeling (*Objective 4*) suggest pronghorn management should prioritize adult female survival rates to achieve population objectives, given the importance of adult female survival on population growth. Managers should consider the best management options for manipulating these rates, either through harvest or controlling other sources of mortality. There was uncertainty in estimates of 4-month recruitment and juvenile survival due to lack of data on these important vital rates. Additional information regarding neonatal and juvenile survival could improve our understanding of these vital rates and inform IPM specifications for future use. Results from the IPM were highly sensitive to assumptions regarding the knowledge and confidence in aerial counts. Thus, we recommend assessing the current survey and inventory program for pronghorn, which could include considering counting methods that provide uncertainty in counts (e.g., a distance sampling design).

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Appendix A: Literature review related to pronghorn vital rates

Population models

- Berger and Conner 2008
    - Vital rates used to construct demographic models (not clarified but assume rates exclusive of human harvests):
        - 0.070 (variance = 0.006) summer survival of fawns 0-2 months (wolf sites)
        - 0.354 (variance = 0.006) summer survival of fawns 0-2 months (wolf-free sites)
        - 0.836 (variance = 0.005) winter survival of juveniles 2-12 months
        - 0.872 (variance = 0.006) annual survival of yearlings 1-2 years
        - 0.872 (variance = 0.006) annual survival of adults 2+ years
        - 0.95 (variance = 0.0003) fertility of adults 2+years

Age ratios

- Fawn:adult female ratio
    - 53:100 during summer 1964, Glasgow herd, MT (Martinka 1967)
    - 39:100 during summer 1965 after severe winter with substantial mortalities, MT (Martinka 1967)
    - 55:100 during summer 1965 after severe winter, Saskatchewan (Martinka 1967)
    - 90-110:100 during most summers prior to 1965, MT & Saskatchewan (Martinka 1967)
    - 90:100 during summer 1965, Malta herd, MT (Martinka 1967)
    - 43-95:100 during August 1960-70s, ID (Bodie 1978)
    - 58:100 during summer 1977, Alberta (Barrett 1982)
    - 42-115:100 during summers 1968-78, aerial surveys, Yellow Water Triangle, MT (Pyrah 1987)
    - 43 to >100:100 throughout pronghorn range (O'Gara 2004c)
    - 20-117:100 during autumn 1985-1996, UT (Beale 1978)
- Yearling:adult female ratio
    - 103:100 during summer 1963, Glasgow herd, MT (Martinka 1967)
        - No age class definitions, but based on aerial surveys, likely 1-1.5 years old
    - 110:100 during summer in 1960's, Saskatchewan (Martinka 1967)
        - No age class definitions, but based on aerial surveys, likely 1-1.5 years old

Sex ratios

- Male fawn:female fawn ratio
    - 1.1-1.2:1 from tagged fawns, MT (Martinka 1967)
    - 1:1 (Byers and Moodie 1990, Fairbanks 1993)
- Adult male:adult female ratio
    - 86-93:100 during summer 1963-1964, Glasgow herd, MT (Martinka 1967)
        - >1.5 years old; based on aerial surveys
    - 45:100 during summer 1965 after severe winter with substantial mortalities, Glasgow herd, MT (Martinka 1967)
        - >1.5 years old; based on aerial surveys

Survival rates (sex- & age-class)

- Fawn survival
    - 0.379 surviving from birth until 01 Aug (n = 29 fawns), ID 1976 (Bodie 1978)
    - 0.354 surviving from birth until 60 days (n = 62 fawns), Alberta 1975-76 (Barrett 1978, 1984)
    - 0.365 surviving from birth until 4 months (n = 200), UT 1970's (Beale 1978)
    - 0.31 (0.19-0.43) average surviving from birth until 15 months during 1966-77, aerial surveys, Yellow Water Triangle, MT (Pyrah 1987)
    - 0.433 (0.22-0.6) average marked fawns surviving from birth until weaning (n = 58), CO 1988-90 (Fairbanks 1993)
    - 0.42 (SE = 0.04) mean annual survival of radio-collared fawns during 2015-16, ID (Panting et al. 2018)
    - In areas used by migratory pronghorn: At low elevations/winter snow, fawn survival positively associated with wolf density (0.0 – 0.42; average 0.25); At high elevations/winter snow, fawn survival unassociated with wolf

density (0.70). Across average snow depths, fawn survival averaged 0.47 in low wolf density areas and 0.59 in high wolf density areas. Based on monitoring fawns of 44 GPS collared adult females in Yellowstone's northern range during spring, summer, and early fall 1999-2006 (Barnowe-Meyer et al. 2010)

  - 0.049 – 0.440 60-day survival rates of VHF collared neonatal fawns (n = 108) monitored from birth in 2002 & 2003 in Grant Teton National Park (Berger et al. 2008)
  - 0.082 (1st month), 0.429 (2nd month), 0.035 (2-month survival) for male fawns at wolf-free site (Berger and Conner 2008)
  - 0.168 (1st month), 0.631 (2nd month), 0.106 (2-month survival) for female fawns at wolf-free site (Berger and Conner 2008)
  - 0.292 (1st month), 0.777 (2nd month), 0.227 (2-month survival) for male fawns at wolf-abundant site (Berger and Conner 2008)
  - 0.484 (1st month), 0.888 (2nd month), 0.429 (2-month survival) for female fawns at wolf-abundant site (Berger and Conner 2008)
  - 0.58-0.71 annual survival, 0.66 6-month survival of marked fawns (n = 92; Kauth 2017)
- Yearling survival
  - 0.92-0.95 post-hunt (Nov-Apr) survival of marked yearling (6-18 months) females 2002-05, SD, no harvested individuals (Jacques et al. 2007)
- Adult survival
  - 0.82 & 0.68 annual survival of marked animals in hunted population during 1983 & 1984, CO, 36% of mortalities were harvests (Firchow 1986).
    - Likely >1.5 years old, no indication of sex-specific rates
  - 0.858 (Feb 2016-Feb 2017) & 0.941 (Feb 2017-Feb 2018) annual survival of marked animals (sexes combined) in hunted population in CO, 12-16% of mortalities were harvested. (Stiver 2018)
- Adult female survival
  - 0.73 (range during normal years: 0.77-0.97; as low as 0.19 in years with harsh winters) annual survival, 0.82 winter survival, 0.91 summer survival, 0.97 during mean 20-day spring migration period, & 1.0 during mean 10-day fall migration period in SE Alberta 2004-2007, northcentral MT and SW Saskatchewan, GPS collar study, 2004-2011. Assume these are hunted populations (at least MT populations), but not clarified in paper and no hunting related mortalities reported (Jones et al. 2020)
  - 0.84 – 0.97 annual survival, WY, no hunting-related mortalities reported. (Sawyer and Lindzey 2000)
  - 0.82 annual survival, TX, no hunting-related mortalities reported. (Canon and Bryant 2006)
  - 0.801 annual survival of collared females (n=24) in unhunted population in Custer State Park, SD. Mortality due primarily to predation from lions and coyotes (Keller et al. 2013)
  - 1.0 (winter; Nov-Mar), 0.791 (parturition; Mar-Jul), and 0.977 (breeding; Aug-Oct) seasonal survival rates of collared adult females (n=24) in unhunted population in Custer State Park, SD (Keller et al. 2013)
  - ~0.9 – 0.98 (during winter, spring, and summer) and ~0.8 fall (hunting season) survival of collared females (n=74), ND (Kolar et al. 2012)
  - 0.82 (1 yr; Jan-Dec 2015), 0.76 (2 yrs; Jan 2015-Dec 2016), 0.93 (in 3rd year given survival of first 2 years), 0.62 (across 31 months; Jan 2015-July 2017), GPS collar study in hunted population, OR, but no reporting of any cause of death data (Larkins et al. 2018)
  - 0.97 (Jan-May 2010), 0.53 (Oct-Apr 2010-11), 0.91 (Nov-Apr 2011-12) winter survival of GPS collared females (n = 47) in hunted population, WY, 2 animals were harvested (Taylor et al. 2016)
  - 0.73-0.94 annual survival in 2 hunted herds; 0.82-0.96 annual survival without harvest effects based on collared animals (some yearlings included in the captures), SW WY (Grogan and Lindzey 2010)
  - 0.82 – 0.89 annual survival, 0.92-1.00 post-hunt (Nov-Apr) survival, 0.87-1.0 pre-hunt (May-Sep) survival, 0.90-1.00 hunt (Oct) survival of marked females 2002-05 in hunted populations, SD (Jacques et al. 2007)
  - 0.85-0.89 annual survival of marked adult females (>18 months; n = 107) in hunted population, SD, 2 animals harvested. (Kauth 2017)

- Adult male survival
  - 0.76 (0.702 – 0.891) mean annual survival of collared males (n=26) in unhunted population, Custer State Park, SD. Mortality due primarily to predation from lions and coyotes (Keller et al. 2013)
  - 0.944 (winter; Nov-Mar), 0.837 (parturition; Mar-Jul), and 0.957 (breeding; Aug-Oct) seasonal survival rates of collared adult males (n=26) in unhunted population, Custer State Park, SD. (Keller et al. 2013)
  - ~0.9 – 0.98 (during winter, spring, and summer) and ~0.4 fall (hunting season) survival of collared males (n=60), ND (Kolar et al. 2012)
  - 1.00 annual survival, no hunting-related mortalities reported, collared males not permitted to be hunted, TX (Canon and Bryant 2006)

<u>Harvest mortality rates</u>

- Fawn
  - 10% (5-19%) average annual winter mortality during 1966-77, Yellow Water Triangle, MT based on aerial surveys (Pyrah 1987)
- Adults
  - 23% (15-31%) average annual harvest mortality for both sexes during 1966-77, Yellow Water Triangle, MT based on aerial surveys (Pyrah 1987)
    - >10.5 months old
  - 45% average annual mortality for both sexes in which an average of 52.2% of the summer population was harvested during 1960-63, Alberta (Mitchell 1980)
  - 37.9% average annual mortality for both sexes in which an average of 18% of the summer population was harvested during 1960-64, Alberta (Mitchell 1980)
  - 29% average annual mortality for both sexes in which an average of 7.9% of the summer population was harvested in 1964, Alberta (Mitchell 1980)
- Adult males
  - 41% (22-54%) average annual harvest mortality during 1966-77, Yellow Water Triangle, MT based on aerial surveys (Pyrah 1987)
    - >10.5 months old
- Adult females
  - 9% (5-19%) average annual harvest mortality during 1966-77, Yellow Water Triangle, MT based on aerial surveys (Pyrah 1987)
    - >10.5 months old

<u>Natural mortality rates</u>

- Fawn
  - 25% (10-48%) average annual winter mortality during 1966-77, Yellow Water Triangle, MT (Pyrah 1987)
  - 89 & 80% annual mortality during 1983 & 1984, CO, mark-resight study (Firchow 1986)
  - 25-65% during first 2-3 months throughout most of their range (O'Gara 2004*a*)
  - Predation most common proximate cause of death for fawns (>67%; n = 28) on Yellowstone's northern range (Barnowe-Meyer et al. 2009)
- Adults
  - 24% (9-53%) average annual winter mortality for both sexes during 1966-77, Yellow Water Triangle, MT (Pyrah 1987)
    - >10.5 months old
- Adult males
  - 10% (0-27%) average annual winter mortality during 1966-77, Yellow Water Triangle, MT (Pyrah 1987)
    - >10.5 months old
- Adult females
  - 10% (0-24%) average annual winter mortality during 1966-77, Yellow Water Triangle, MT (Pyrah 1987)
    - >10.5 months old

    - Predation most common proximate cause of death for adult female (59% of mortalities, n = 22) on Yellowstone's northern range (Barnowe-Meyer et al. 2009)
    - Predation most common cause of death for adult female (69.5% of mortalities, n = 23), Custer State Park, SD (Keller et al. 2013)

<u>Pregnancy rates</u>

- Fertility is high, both sexes achieve sexual maturity as yearlings (female fawns may conceive and produce young under favorable conditions). Evidence indicates a rather constant, high maternal investment into offspring by females and fecundity rates are not correlated strongly with weather, habitat, or physiological condition of the female (Kohlmann 2004)
- 98% in CO (Firchow 1986)

<u>Litter size</u>

- 1.4 – 1.8 fawns per adult female, UT (Beale 1978)
- 1.84 – 1.98 fawns per adult female in CO, WY, NM, elsewhere (Ellis 1972)
- 1.85 – 1.97 fetal fawns per adult female (show little variation among years or regions across nearly all western states; Kohlmann 2004)

<u>Detection probabilities</u>

- 0.643-0.666 unconditional parameter estimates for resighting probabilities of pronghorn based on spring (May-June) aerial flights of marked adult females in SD across 3 years (Jacques et al. 2014)

Appendix B: Estimates of mean annual vital rates by hunting district

Table B1. Mean pronghorn annual vital rate estimates and 95% credible intervals (LCL and UCL) in 9 hunting districts (HD) across Montana from 2004 – 2021/22.

HD	Vital Rate	Year	Mean	LCL	UCL
313	Adult Female Survival	2016	0.749	0.561	0.885
		2017	0.656	0.452	0.84
		2018	0.781	0.629	0.891
		2019	0.759	0.592	0.886
		2020	0.625	0.532	0.717
		2021	0.844	0.777	0.904
		2022	0.767	0.616	0.88
	Adult Male Survival	2016	0.396	0.187	0.618
		2017	0.434	0.262	0.611
		2018	0.537	0.364	0.696
		2019	0.28	0.119	0.46
		2020	0.337	0.16	0.543
		2021	0.291	0.135	0.47
		2022	0.325	0.156	0.525
	Juvenile Female Survival	2016	0.703	0.505	0.855
		2017	0.669	0.461	0.84
		2018	0.709	0.513	0.86
		2019	0.712	0.518	0.86
		2020	0.71	0.519	0.858
		2021	0.711	0.517	0.86
		2022	0.714	0.52	0.862
	Juvenile Male Survival	2016	0.692	0.488	0.852
		2017	0.684	0.493	0.842
		2018	0.715	0.523	0.862
		2019	0.717	0.525	0.863
		2020	0.74	0.565	0.871
		2021	0.716	0.524	0.863
		2022	0.714	0.519	0.862
	Adult Female Harvest Rate	2016	0	0	0
		2017	0	0	0
		2018	0.037	0.013	0.077
		2019	0	0	0
		2020	0	0	0
		2021	0	0	0
		2022	0.061	0.026	0.114
	Adult Male Harvest Rate	2016	0.332	0.151	0.576
		2017	0.274	0.159	0.418
		2018	0.207	0.116	0.326
		2019	0.529	0.308	0.776
		2020	0.422	0.238	0.628
		2021	0.468	0.282	0.673
		2022	0.431	0.248	0.633
	Adult Female Other Mortality	2016	0.251	0.115	0.439
		2017	0.344	0.16	0.548
		2018	0.182	0.085	0.323
		2019	0.241	0.114	0.408
		2020	0.375	0.283	0.468
		2021	0.156	0.096	0.223
		2022	0.172	0.084	0.298
	Adult Male Other Mortality	2016	0.272	0.158	0.412
		2017	0.292	0.171	0.435
		2018	0.256	0.145	0.393
		2019	0.191	0.076	0.343
		2020	0.241	0.144	0.36
		2021	0.242	0.142	0.366

HD	Vital Rate	Year	Mean	LCL	UCL
		2022	0.243	0.144	0.367
	Recruitment	2017	0.758	0.468	1.137
		2018	0.274	0.098	0.621
		2019	0.34	0.146	0.695
		2020	0.864	0.203	1.833
		2021	0.477	0.073	1.152
		2022	0.42	0.124	1.369
	lambda	2017	1.009	0.817	1.201
		2018	0.719	0.598	0.873
		2019	0.892	0.758	1.069
		2020	1.086	0.751	1.5
		2021	0.833	0.634	1.118
		2022	0.877	0.699	1.392
318	Adult Female Survival	2004	0.758	0.623	0.862
		2005	0.805	0.676	0.896
		2006	0.763	0.665	0.838
		2007	0.726	0.632	0.8
		2008	0.729	0.625	0.808
		2009	0.736	0.636	0.812
		2010	0.654	0.555	0.736
		2011	0.667	0.572	0.745
		2012	0.637	0.529	0.72
		2013	0.732	0.623	0.817
		2014	0.666	0.56	0.752
		2015	0.654	0.556	0.733
		2016	0.675	0.576	0.754
		2017	0.697	0.603	0.772
		2018	0.637	0.536	0.721
		2019	0.762	0.661	0.843
		2020	0.818	0.767	0.864
		2021	0.812	0.766	0.855
	Adult Male Survival	2004	0.461	0.263	0.636
		2005	0.442	0.256	0.617
		2006	0.288	0.138	0.455
		2007	0.293	0.163	0.443
		2008	0.265	0.122	0.441
		2009	0.308	0.173	0.46
		2010	0.26	0.126	0.42
		2011	0.315	0.137	0.486
		2012	0.254	0.114	0.413
		2013	0.409	0.251	0.577
		2014	0.341	0.181	0.514
		2015	0.373	0.239	0.508
		2016	0.379	0.23	0.528
		2017	0.333	0.21	0.46
		2018	0.32	0.186	0.459
		2019	0.46	0.307	0.605
		2020	0.448	0.291	0.599
		2021	0.429	0.265	0.596
	Juvenile Female Survival	2004	0.727	0.541	0.868
		2005	0.734	0.551	0.871
		2006	0.739	0.556	0.875
		2007	0.743	0.565	0.878
		2008	0.761	0.595	0.885
		2009	0.746	0.569	0.876
		2010	0.752	0.584	0.879
		2011	0.75	0.575	0.878
		2012	0.765	0.605	0.884
		2013	0.749	0.579	0.877
		2014	0.766	0.603	0.885
		2015	0.751	0.585	0.877

HD	Vital Rate	Year	Mean	LCL	UCL
		2016	0.753	0.591	0.877
		2017	0.732	0.552	0.87
		2018	0.729	0.546	0.869
		2019	0.717	0.526	0.863
		2020	0.712	0.516	0.862
		2021	0.714	0.52	0.861
	Juvenile Male Survival	2004	0.711	0.517	0.86
		2005	0.698	0.498	0.855
		2006	0.69	0.484	0.849
		2007	0.703	0.512	0.855
		2008	0.673	0.478	0.836
		2009	0.698	0.504	0.852
		2010	0.673	0.474	0.841
		2011	0.695	0.494	0.852
		2012	0.649	0.44	0.831
		2013	0.683	0.474	0.847
		2014	0.652	0.45	0.826
		2015	0.666	0.46	0.838
		2016	0.677	0.482	0.84
		2017	0.699	0.504	0.853
		2018	0.685	0.49	0.847
		2019	0.692	0.493	0.85
		2020	0.701	0.502	0.854
		2021	0.714	0.519	0.862
	Adult Female Harvest Rate	2004	0.016	0.009	0.027
		2005	0.009	0.005	0.016
		2006	0.082	0.057	0.113
		2007	0.112	0.084	0.148
		2008	0.108	0.081	0.142
		2009	0.101	0.079	0.124
		2010	0.187	0.148	0.23
		2011	0.182	0.141	0.234
		2012	0.206	0.161	0.268
		2013	0.094	0.069	0.12
		2014	0.169	0.128	0.215
		2015	0.176	0.142	0.211
		2016	0.172	0.135	0.214
		2017	0.136	0.108	0.165
		2018	0.177	0.142	0.216
		2019	0.067	0.048	0.088
		2020	0.052	0.037	0.069
		2021	0.065	0.045	0.087
	Adult Male Harvest Rate	2004	0.202	0.095	0.434
		2005	0.21	0.106	0.427
		2006	0.494	0.317	0.687
		2007	0.487	0.326	0.636
		2008	0.522	0.34	0.712
		2009	0.464	0.314	0.613
		2010	0.525	0.349	0.704
		2011	0.459	0.281	0.696
		2012	0.529	0.354	0.729
		2013	0.296	0.178	0.425
		2014	0.402	0.249	0.584
		2015	0.353	0.258	0.441
		2016	0.374	0.254	0.513
		2017	0.414	0.305	0.524
		2018	0.427	0.307	0.569
		2019	0.247	0.175	0.322
		2020	0.254	0.168	0.357
		2021	0.282	0.17	0.395
	Adult Female Other Mortality	2004	0.226	0.123	0.36

HD	Vital Rate	Year	Mean	LCL	UCL
		2005	0.186	0.096	0.314
		2006	0.155	0.086	0.249
		2007	0.161	0.093	0.253
		2008	0.163	0.092	0.266
		2009	0.163	0.092	0.26
		2010	0.158	0.091	0.248
		2011	0.151	0.088	0.235
		2012	0.157	0.091	0.247
		2013	0.174	0.092	0.283
		2014	0.165	0.095	0.26
		2015	0.169	0.099	0.263
		2016	0.152	0.084	0.247
		2017	0.167	0.098	0.258
		2018	0.186	0.108	0.288
		2019	0.172	0.096	0.269
		2020	0.131	0.087	0.179
		2021	0.123	0.085	0.164
	Adult Male Other Mortality	2004	0.337	0.19	0.503
		2005	0.348	0.192	0.527
		2006	0.218	0.125	0.337
		2007	0.22	0.127	0.338
		2008	0.212	0.121	0.329
		2009	0.228	0.135	0.345
		2010	0.215	0.122	0.332
		2011	0.227	0.124	0.355
		2012	0.217	0.119	0.341
		2013	0.295	0.174	0.436
		2014	0.257	0.152	0.386
		2015	0.274	0.165	0.403
		2016	0.247	0.139	0.385
		2017	0.253	0.153	0.376
		2018	0.253	0.15	0.377
		2019	0.293	0.172	0.435
		2020	0.298	0.172	0.448
		2021	0.289	0.168	0.435
	Recruitment	2005	0.847	0.378	1.758
		2006	0.677	0.236	1.26
		2007	0.48	0.271	0.873
		2008	1.004	0.484	1.714
		2009	0.673	0.459	1.087
		2010	0.749	0.298	1.44
		2011	0.513	0.191	1.192
		2012	0.865	0.368	1.729
		2013	0.615	0.372	1.158
		2014	1.152	0.544	1.89
		2015	0.762	0.543	1.159
		2016	0.887	0.44	1.457
		2017	0.567	0.399	0.837
		2018	0.645	0.357	1.014
		2019	0.464	0.332	0.698
		2020	0.451	0.184	0.852
		2021	0.888	0.617	1.401
	lambda	2005	1.155	0.869	1.689
		2006	1.076	0.827	1.394
		2007	0.899	0.778	1.09
		2008	1.144	0.898	1.444
		2009	0.992	0.855	1.201
		2010	1.012	0.793	1.318
		2011	0.836	0.667	1.12
		2012	1.003	0.784	1.345
		2013	0.855	0.722	1.077

HD	Vital Rate	Year	Mean	LCL	UCL
		2014	1.233	0.931	1.548
		2015	0.977	0.846	1.166
		2016	0.993	0.821	1.191
		2017	0.877	0.769	1.005
		2018	0.905	0.782	1.041
		2019	0.789	0.698	0.901
		2020	0.908	0.776	1.099
		2021	1.187	1.029	1.471
360	Adult Female Survival	2004	0.792	0.697	0.865
		2005	0.734	0.626	0.818
		2006	0.764	0.676	0.833
		2007	0.714	0.624	0.784
		2008	0.749	0.663	0.815
		2009	0.765	0.694	0.823
		2010	0.748	0.677	0.805
		2011	0.775	0.705	0.831
		2012	0.778	0.706	0.836
		2013	0.751	0.679	0.81
		2014	0.736	0.651	0.803
		2015	0.725	0.635	0.797
		2016	0.719	0.62	0.797
		2017	0.69	0.588	0.77
		2018	0.705	0.6	0.786
		2019	0.737	0.631	0.821
		2020	0.76	0.703	0.815
		2021	0.812	0.761	0.859
	Adult Male Survival	2004	0.325	0.119	0.518
		2005	0.27	0.108	0.433
		2006	0.273	0.152	0.406
		2007	0.323	0.196	0.454
		2008	0.305	0.175	0.442
		2009	0.374	0.227	0.525
		2010	0.386	0.243	0.527
		2011	0.375	0.242	0.505
		2012	0.316	0.185	0.452
		2013	0.355	0.218	0.488
		2014	0.327	0.192	0.465
		2015	0.353	0.222	0.478
		2016	0.303	0.183	0.426
		2017	0.28	0.164	0.402
		2018	0.23	0.125	0.351
		2019	0.312	0.179	0.449
		2020	0.35	0.195	0.51
		2021	0.439	0.267	0.603
	Juvenile Female Survival	2004	0.747	0.57	0.878
		2005	0.744	0.566	0.876
		2006	0.759	0.593	0.882
		2007	0.76	0.595	0.883
		2008	0.772	0.612	0.888
		2009	0.776	0.618	0.888
		2010	0.774	0.621	0.888
		2011	0.756	0.587	0.88
		2012	0.759	0.59	0.883
		2013	0.761	0.597	0.883
		2014	0.767	0.602	0.887
		2015	0.754	0.58	0.879
		2016	0.742	0.561	0.875
		2017	0.737	0.557	0.872
		2018	0.74	0.557	0.874
		2019	0.743	0.562	0.877
		2020	0.722	0.53	0.865

HD	Vital Rate	Year	Mean	LCL	UCL
		2021	0.715	0.522	0.862
	Juvenile Male Survival	2004	0.722	0.538	0.863
		2005	0.724	0.544	0.864
		2006	0.693	0.503	0.849
		2007	0.685	0.494	0.843
		2008	0.656	0.451	0.835
		2009	0.687	0.489	0.846
		2010	0.704	0.514	0.855
		2011	0.715	0.535	0.859
		2012	0.71	0.517	0.859
		2013	0.721	0.538	0.863
		2014	0.737	0.558	0.871
		2015	0.747	0.581	0.875
		2016	0.747	0.582	0.874
		2017	0.747	0.583	0.875
		2018	0.712	0.531	0.858
		2019	0.694	0.5	0.851
		2020	0.699	0.502	0.854
		2021	0.715	0.522	0.862
	Adult Female Harvest Rate	2004	0.051	0.038	0.067
		2005	0.081	0.065	0.1
		2006	0.082	0.065	0.103
		2007	0.133	0.107	0.164
		2008	0.101	0.079	0.129
		2009	0.095	0.078	0.114
		2010	0.12	0.1	0.142
		2011	0.088	0.073	0.106
		2012	0.084	0.069	0.101
		2013	0.105	0.087	0.124
		2014	0.106	0.088	0.127
		2015	0.111	0.091	0.133
		2016	0.115	0.094	0.138
		2017	0.128	0.103	0.157
		2018	0.119	0.094	0.15
		2019	0.081	0.061	0.107
		2020	0.077	0.06	0.096
		2021	0.054	0.039	0.072
	Adult Male Harvest Rate	2004	0.457	0.247	0.766
		2005	0.521	0.331	0.777
		2006	0.482	0.365	0.621
		2007	0.41	0.314	0.534
		2008	0.43	0.319	0.573
		2009	0.349	0.236	0.494
		2010	0.339	0.241	0.463
		2011	0.357	0.262	0.475
		2012	0.428	0.315	0.563
		2013	0.386	0.284	0.511
		2014	0.428	0.324	0.557
		2015	0.419	0.321	0.549
		2016	0.478	0.371	0.608
		2017	0.496	0.386	0.622
		2018	0.554	0.433	0.687
		2019	0.435	0.323	0.575
		2020	0.387	0.257	0.557
		2021	0.297	0.191	0.438
	Adult Female Other Mortality	2004	0.157	0.086	0.252
		2005	0.184	0.101	0.295
		2006	0.154	0.088	0.241
		2007	0.153	0.086	0.241
		2008	0.15	0.088	0.231
		2009	0.14	0.083	0.213

HD	Vital Rate	Year	Mean	LCL	UCL
		2010	0.132	0.076	0.206
		2011	0.137	0.081	0.208
		2012	0.138	0.081	0.212
		2013	0.145	0.087	0.219
		2014	0.158	0.093	0.244
		2015	0.164	0.092	0.257
		2016	0.166	0.09	0.267
		2017	0.182	0.104	0.284
		2018	0.176	0.1	0.278
		2019	0.182	0.102	0.286
		2020	0.163	0.111	0.219
		2021	0.134	0.09	0.182
	Adult Male Other Mortality	2004	0.217	0.092	0.362
		2005	0.21	0.089	0.356
		2006	0.245	0.15	0.356
		2007	0.267	0.163	0.388
		2008	0.265	0.162	0.385
		2009	0.276	0.166	0.413
		2010	0.276	0.164	0.407
		2011	0.268	0.162	0.397
		2012	0.256	0.155	0.377
		2013	0.259	0.156	0.384
		2014	0.245	0.148	0.362
		2015	0.228	0.131	0.346
		2016	0.219	0.125	0.336
		2017	0.224	0.138	0.326
		2018	0.216	0.131	0.318
		2019	0.252	0.154	0.371
		2020	0.263	0.157	0.39
		2021	0.264	0.154	0.401
	Recruitment	2005	0.519	0.456	0.587
		2006	0.848	0.728	0.98
		2007	0.701	0.6	0.808
		2008	0.858	0.402	1.537
		2009	0.699	0.597	0.81
		2010	0.604	0.525	0.69
		2011	0.452	0.389	0.52
		2012	0.503	0.423	0.589
		2013	0.491	0.424	0.564
		2014	0.662	0.574	0.756
		2015	0.553	0.48	0.632
		2016	0.518	0.442	0.601
		2017	0.584	0.496	0.682
		2018	0.657	0.562	0.76
		2019	0.709	0.342	1.288
		2020	0.544	0.44	0.659
		2021	0.544	0.442	0.658
	lambda	2005	1.002	0.911	1.09
		2006	1.12	0.997	1.231
		2007	1.041	0.951	1.127
		2008	1.064	0.867	1.331
		2009	1.005	0.909	1.097
		2010	0.991	0.915	1.062
		2011	0.904	0.838	0.964
		2012	0.947	0.877	1.015
		2013	0.948	0.879	1.012
		2014	1.036	0.961	1.108
		2015	0.959	0.885	1.027
		2016	0.92	0.843	0.991
		2017	0.933	0.844	1.013
		2018	0.945	0.855	1.027

HD	Vital Rate	Year	Mean	LCL	UCL
		2019	0.961	0.792	1.211
		2020	0.93	0.831	1.024
		2021	0.939	0.857	1.021
420	Adult Female Survival	2004	0.717	0.639	0.78
		2005	0.658	0.575	0.723
		2006	0.827	0.733	0.894
		2007	0.693	0.602	0.766
		2008	0.786	0.694	0.858
		2009	0.799	0.705	0.874
		2010	0.838	0.747	0.906
		2011	0.842	0.752	0.91
		2012	0.767	0.633	0.87
		2013	0.782	0.667	0.873
		2014	0.844	0.743	0.911
		2015	0.846	0.767	0.906
		2016	0.872	0.808	0.92
		2017	0.844	0.776	0.897
		2018	0.822	0.723	0.901
		2019	0.788	0.69	0.869
		2020	0.751	0.673	0.832
		2021	0.897	0.856	0.933
	Adult Male Survival	2004	0.442	0.208	0.609
		2005	0.403	0.284	0.513
		2006	0.438	0.335	0.532
		2007	0.356	0.238	0.471
		2008	0.556	0.427	0.667
		2009	0.595	0.459	0.709
		2010	0.539	0.351	0.71
		2011	0.531	0.36	0.686
		2012	0.524	0.373	0.662
		2013	0.574	0.406	0.719
		2014	0.626	0.46	0.762
		2015	0.512	0.37	0.636
		2016	0.63	0.518	0.726
		2017	0.598	0.486	0.693
		2018	0.47	0.328	0.605
		2019	0.425	0.291	0.552
		2020	0.536	0.4	0.652
		2021	0.476	0.329	0.604
	Juvenile Female Survival	2004	0.732	0.548	0.871
		2005	0.742	0.565	0.874
		2006	0.736	0.554	0.872
		2007	0.734	0.554	0.87
		2008	0.737	0.555	0.873
		2009	0.722	0.53	0.866
		2010	0.721	0.532	0.865
		2011	0.72	0.53	0.864
		2012	0.702	0.503	0.856
		2013	0.715	0.524	0.862
		2014	0.735	0.552	0.872
		2015	0.758	0.596	0.881
		2016	0.76	0.598	0.881
		2017	0.772	0.611	0.885
		2018	0.684	0.481	0.847
		2019	0.683	0.483	0.845
		2020	0.708	0.511	0.854
		2021	0.714	0.518	0.862
	Juvenile Male Survival	2004	0.741	0.564	0.873
		2005	0.751	0.586	0.875
		2006	0.747	0.579	0.875
		2007	0.747	0.578	0.876

HD	Vital Rate	Year	Mean	LCL	UCL
		2008	0.767	0.61	0.885
		2009	0.729	0.547	0.868
		2010	0.679	0.474	0.844
		2011	0.685	0.479	0.849
		2012	0.728	0.547	0.866
		2013	0.723	0.534	0.866
		2014	0.779	0.633	0.889
		2015	0.775	0.623	0.888
		2016	0.784	0.637	0.892
		2017	0.808	0.679	0.904
		2018	0.666	0.462	0.836
		2019	0.67	0.47	0.835
		2020	0.724	0.556	0.856
		2021	0.714	0.52	0.861
	Adult Female Harvest Rate	2004	0.163	0.131	0.202
		2005	0.228	0.191	0.267
		2006	0.047	0.033	0.062
		2007	0.162	0.134	0.194
		2008	0.057	0.041	0.075
		2009	0.036	0.024	0.05
		2010	0.02	0.012	0.031
		2011	0.018	0.01	0.029
		2012	0.024	0.015	0.037
		2013	0.03	0.018	0.045
		2014	0.039	0.023	0.059
		2015	0.034	0.021	0.05
		2016	0.029	0.018	0.042
		2017	0.041	0.028	0.057
		2018	0.025	0.016	0.037
		2019	0.038	0.026	0.052
		2020	0.034	0.023	0.048
		2021	0.018	0.011	0.029
	Adult Male Harvest Rate	2004	0.372	0.23	0.627
		2005	0.425	0.329	0.534
		2006	0.396	0.329	0.47
		2007	0.462	0.37	0.566
		2008	0.229	0.172	0.297
		2009	0.141	0.103	0.187
		2010	0.088	0.057	0.127
		2011	0.127	0.081	0.19
		2012	0.171	0.112	0.247
		2013	0.132	0.083	0.195
		2014	0.132	0.076	0.206
		2015	0.265	0.198	0.343
		2016	0.191	0.142	0.25
		2017	0.22	0.168	0.283
		2018	0.214	0.174	0.257
		2019	0.284	0.216	0.367
		2020	0.212	0.158	0.278
		2021	0.266	0.214	0.323
	Adult Female Other Mortality	2004	0.12	0.064	0.199
		2005	0.114	0.058	0.201
		2006	0.127	0.06	0.222
		2007	0.145	0.079	0.234
		2008	0.157	0.089	0.247
		2009	0.165	0.093	0.258
		2010	0.142	0.077	0.231
		2011	0.14	0.075	0.228
		2012	0.208	0.109	0.341
		2013	0.188	0.101	0.301
		2014	0.118	0.053	0.218

HD	Vital Rate	Year	Mean	LCL	UCL
		2015	0.12	0.065	0.194
		2016	0.1	0.055	0.16
		2017	0.115	0.066	0.181
		2018	0.153	0.078	0.249
		2019	0.174	0.096	0.271
		2020	0.214	0.135	0.293
		2021	0.084	0.052	0.122
	Adult Male Other Mortality	2004	0.187	0.103	0.296
		2005	0.172	0.094	0.28
		2006	0.166	0.09	0.265
		2007	0.181	0.102	0.283
		2008	0.215	0.126	0.33
		2009	0.264	0.158	0.395
		2010	0.373	0.209	0.559
		2011	0.341	0.198	0.51
		2012	0.305	0.183	0.448
		2013	0.294	0.167	0.448
		2014	0.242	0.12	0.402
		2015	0.223	0.129	0.343
		2016	0.179	0.105	0.274
		2017	0.181	0.107	0.278
		2018	0.316	0.189	0.453
		2019	0.291	0.172	0.427
		2020	0.252	0.147	0.384
		2021	0.257	0.146	0.395
	Recruitment	2005	0.659	0.571	0.756
		2006	0.417	0.289	0.589
		2007	0.461	0.366	0.571
		2008	0.516	0.377	0.691
		2009	0.198	0.145	0.262
		2010	0.2	0.137	0.28
		2011	0.239	0.078	0.463
		2012	0.268	0.191	0.361
		2013	0.262	0.175	0.374
		2014	0.757	0.547	1.029
		2015	0.877	0.614	1.22
		2016	0.481	0.35	0.65
		2017	0.669	0.455	0.906
		2018	0.404	0.343	0.472
		2019	0.551	0.399	0.737
		2020	0.533	0.392	0.702
		2021	0.433	0.364	0.511
	lambda	2005	0.986	0.908	1.061
		2006	0.816	0.752	0.875
		2007	0.96	0.887	1.03
		2008	0.884	0.814	0.952
		2009	0.836	0.775	0.891
		2010	0.841	0.769	0.907
		2011	0.889	0.784	1.015
		2012	0.927	0.837	1.012
		2013	0.866	0.762	0.957
		2014	1.181	1.055	1.316
		2015	1.278	1.132	1.451
		2016	1.013	0.93	1.1
		2017	1.164	1.057	1.282
		2018	0.979	0.923	1.028
		2019	0.979	0.893	1.073
		2020	0.954	0.866	1.046
		2021	0.924	0.854	0.989
481	Adult Female Survival	2004	0.685	0.574	0.767
		2005	0.72	0.651	0.777

HD	Vital Rate	Year	Mean	LCL	UCL
		2006	0.632	0.508	0.733
		2007	0.535	0.41	0.642
		2008	0.628	0.523	0.717
		2009	0.649	0.474	0.81
		2010	0.761	0.633	0.867
		2011	0.787	0.669	0.88
		2012	0.803	0.686	0.894
		2013	0.726	0.583	0.868
		2014	0.803	0.669	0.9
		2015	0.842	0.757	0.908
		2016	0.873	0.797	0.928
		2017	0.879	0.807	0.93
		2018	0.914	0.861	0.952
		2019	0.897	0.838	0.941
		2020	0.854	0.805	0.897
		2021	0.78	0.719	0.835
	Adult Male Survival	2004	0.507	0.375	0.62
		2005	0.413	0.285	0.551
		2006	0.35	0.227	0.467
		2007	0.347	0.239	0.448
		2008	0.251	0.13	0.359
		2009	0.373	0.219	0.527
		2010	0.433	0.257	0.614
		2011	0.385	0.232	0.549
		2012	0.452	0.277	0.626
		2013	0.54	0.363	0.702
		2014	0.542	0.366	0.693
		2015	0.591	0.417	0.733
		2016	0.512	0.353	0.658
		2017	0.606	0.405	0.77
		2018	0.607	0.424	0.76
		2019	0.651	0.485	0.792
		2020	0.576	0.403	0.706
		2021	0.58	0.415	0.707
	Juvenile Female Survival	2004	0.728	0.551	0.866
		2005	0.726	0.518	0.876
		2006	0.623	0.411	0.808
		2007	0.675	0.468	0.841
		2008	0.693	0.489	0.854
		2009	0.687	0.464	0.849
		2010	0.701	0.506	0.854
		2011	0.711	0.517	0.86
		2012	0.708	0.515	0.859
		2013	0.697	0.497	0.853
		2014	0.676	0.468	0.841
		2015	0.716	0.535	0.859
		2016	0.742	0.578	0.872
		2017	0.776	0.619	0.892
		2018	0.769	0.599	0.89
		2019	0.849	0.752	0.92
		2020	0.712	0.515	0.861
		2021	0.714	0.519	0.862
	Juvenile Male Survival	2004	0.712	0.542	0.856
		2005	0.553	0.388	0.746
		2006	0.534	0.354	0.719
		2007	0.706	0.515	0.858
		2008	0.744	0.559	0.877
		2009	0.694	0.452	0.856
		2010	0.63	0.416	0.816
		2011	0.687	0.48	0.849
		2012	0.601	0.384	0.8

HD	Vital Rate	Year	Mean	LCL	UCL
		2013	0.688	0.485	0.849
		2014	0.663	0.474	0.825
		2015	0.671	0.477	0.831
		2016	0.625	0.451	0.795
		2017	0.577	0.365	0.782
		2018	0.653	0.436	0.835
		2019	0.539	0.382	0.702
		2020	0.671	0.458	0.843
		2021	0.714	0.52	0.862
	Adult Female Harvest Rate	2004	0.137	0.113	0.169
		2005	0.146	0.13	0.162
		2006	0.156	0.142	0.17
		2007	0.225	0.191	0.265
		2008	0.186	0.151	0.229
		2009	0.053	0.04	0.07
		2010	0.018	0.011	0.026
		2011	0.018	0.011	0.027
		2012	0.015	0.008	0.024
		2013	0.014	0.007	0.022
		2014	0.025	0.014	0.039
		2015	0.026	0.015	0.04
		2016	0.019	0.01	0.031
		2017	0.022	0.013	0.034
		2018	0.012	0.007	0.021
		2019	0.018	0.01	0.027
		2020	0.044	0.034	0.055
		2021	0.084	0.07	0.099
	Adult Male Harvest Rate	2004	0.242	0.182	0.327
		2005	0.251	0.211	0.295
		2006	0.366	0.33	0.403
		2007	0.437	0.351	0.541
		2008	0.581	0.466	0.723
		2009	0.352	0.256	0.485
		2010	0.13	0.096	0.17
		2011	0.169	0.114	0.244
		2012	0.169	0.097	0.276
		2013	0.13	0.075	0.204
		2014	0.179	0.11	0.27
		2015	0.134	0.088	0.189
		2016	0.184	0.129	0.251
		2017	0.094	0.062	0.133
		2018	0.102	0.067	0.149
		2019	0.096	0.058	0.149
		2020	0.184	0.15	0.222
		2021	0.208	0.16	0.272
	Adult Female Other Mortality	2004	0.178	0.093	0.292
		2005	0.134	0.076	0.209
		2006	0.213	0.112	0.336
		2007	0.24	0.124	0.379
		2008	0.186	0.098	0.299
		2009	0.298	0.131	0.479
		2010	0.221	0.118	0.347
		2011	0.195	0.104	0.312
		2012	0.181	0.094	0.297
		2013	0.26	0.121	0.402
		2014	0.172	0.079	0.303
		2015	0.132	0.071	0.213
		2016	0.108	0.058	0.179
		2017	0.099	0.053	0.167
		2018	0.074	0.039	0.123
		2019	0.085	0.045	0.141

HD	Vital Rate	Year	Mean	LCL	UCL
		2020	0.102	0.061	0.15
		2021	0.136	0.083	0.195
	Adult Male Other Mortality	2004	0.252	0.148	0.381
		2005	0.337	0.185	0.485
		2006	0.283	0.169	0.41
		2007	0.216	0.124	0.33
		2008	0.168	0.097	0.26
		2009	0.275	0.168	0.4
		2010	0.437	0.263	0.61
		2011	0.446	0.28	0.609
		2012	0.379	0.222	0.556
		2013	0.33	0.188	0.498
		2014	0.278	0.157	0.433
		2015	0.274	0.15	0.436
		2016	0.304	0.173	0.457
		2017	0.299	0.149	0.492
		2018	0.291	0.15	0.467
		2019	0.253	0.129	0.41
		2020	0.24	0.117	0.409
		2021	0.213	0.105	0.362
	Recruitment	2005	0.751	0.652	0.859
		2006	0.788	0.738	0.841
		2007	0.362	0.278	0.472
		2008	0.435	0.327	0.572
		2009	0.362	0.096	0.707
		2010	0.283	0.236	0.338
		2011	0.084	0.017	0.205
		2012	0.306	0.192	0.46
		2013	0.182	0.107	0.282
		2014	0.615	0.425	0.888
		2015	0.528	0.405	0.64
		2016	0.853	0.62	1.153
		2017	0.704	0.572	0.819
		2018	0.435	0.185	0.872
		2019	1.688	1.036	2.303
		2020	0.537	0.479	0.61
		2021	0.094	0.056	0.143
	lambda	2005	0.96	0.879	1.038
		2006	0.937	0.863	1.005
		2007	0.69	0.623	0.757
		2008	0.677	0.588	0.755
		2009	0.711	0.606	0.841
		2010	0.72	0.573	0.841
		2011	0.719	0.624	0.811
		2012	0.887	0.769	1.006
		2013	0.844	0.739	0.94
		2014	1.055	0.904	1.229
		2015	1.03	0.918	1.128
		2016	1.247	1.153	1.36
		2017	1.132	1.033	1.217
		2018	1.012	0.861	1.273
		2019	1.845	1.4	2.21
		2020	1.046	0.956	1.132
		2021	0.8	0.739	0.856
513	Adult Female Survival	2004	0.668	0.511	0.774
		2005	0.667	0.503	0.769
		2006	0.678	0.512	0.806
		2007	0.65	0.523	0.752
		2008	0.853	0.757	0.918
		2009	0.481	0.188	0.833
		2010	0.608	0.318	0.886

HD	Vital Rate	Year	Mean	LCL	UCL
		2011	0.854	0.665	0.945
		2012	0.879	0.75	0.955
		2013	0.871	0.721	0.957
		2014	0.791	0.501	0.944
		2015	0.791	0.514	0.934
		2016	0.812	0.588	0.938
		2017	0.82	0.638	0.933
		2018	0.898	0.769	0.969
		2019	0.843	0.685	0.94
		2020	0.785	0.724	0.847
		2021	0.869	0.814	0.921
	Adult Male Survival	2004	0.266	0.031	0.513
		2005	0.214	0.029	0.455
		2006	0.282	0.087	0.467
		2007	0.322	0.095	0.527
		2008	0.504	0.354	0.616
		2009	0.214	0.053	0.42
		2010	0.477	0.209	0.703
		2011	0.61	0.418	0.759
		2012	0.56	0.359	0.728
		2013	0.233	0.066	0.483
		2014	0.327	0.09	0.567
		2015	0.435	0.129	0.721
		2016	0.431	0.125	0.704
		2017	0.511	0.188	0.745
		2018	0.608	0.401	0.758
		2019	0.652	0.471	0.776
		2020	0.403	0.108	0.694
		2021	0.547	0.199	0.788
	Juvenile Female Survival	2004	0.718	0.529	0.863
		2005	0.722	0.527	0.874
		2006	0.7	0.507	0.854
		2007	0.717	0.524	0.864
		2008	0.722	0.531	0.866
		2009	0.661	0.447	0.834
		2010	0.707	0.513	0.857
		2011	0.717	0.524	0.862
		2012	0.726	0.538	0.867
		2013	0.725	0.541	0.866
		2014	0.707	0.513	0.859
		2015	0.709	0.511	0.858
		2016	0.721	0.527	0.864
		2017	0.719	0.536	0.861
		2018	0.712	0.496	0.865
		2019	0.723	0.521	0.867
		2020	0.706	0.511	0.859
		2021	0.714	0.52	0.862
	Juvenile Male Survival	2004	0.708	0.518	0.86
		2005	0.701	0.526	0.857
		2006	0.717	0.53	0.863
		2007	0.735	0.559	0.871
		2008	0.724	0.535	0.865
		2009	0.558	0.352	0.763
		2010	0.716	0.528	0.86
		2011	0.72	0.53	0.865
		2012	0.731	0.55	0.869
		2013	0.651	0.43	0.832
		2014	0.658	0.434	0.836
		2015	0.689	0.492	0.849
		2016	0.697	0.502	0.853
		2017	0.717	0.534	0.864

HD	Vital Rate	Year	Mean	LCL	UCL
		2018	0.728	0.542	0.868
		2019	0.736	0.563	0.868
		2020	0.701	0.503	0.856
		2021	0.714	0.518	0.862
	Adult Female Harvest Rate	2004	0.223	0.168	0.299
		2005	0.203	0.162	0.259
		2006	0.155	0.138	0.174
		2007	0.218	0.182	0.266
		2008	0.052	0.042	0.064
		2009	0.045	0.035	0.056
		2010	0.051	0.032	0.077
		2011	0.026	0.016	0.038
		2012	0.021	0.013	0.032
		2013	0.018	0.011	0.028
		2014	0.019	0.012	0.029
		2015	0.023	0.015	0.035
		2016	0.023	0.015	0.035
		2017	0.024	0.016	0.035
		2018	0.009	0.005	0.014
		2019	0.021	0.015	0.028
		2020	0.027	0.021	0.035
		2021	0.013	0.008	0.018
	Adult Male Harvest Rate	2004	0.538	0.304	0.906
		2005	0.604	0.359	0.903
		2006	0.517	0.36	0.592
		2007	0.496	0.35	0.676
		2008	0.302	0.235	0.367
		2009	0.462	0.394	0.534
		2010	0.198	0.135	0.297
		2011	0.17	0.116	0.24
		2012	0.187	0.127	0.269
		2013	0.18	0.127	0.247
		2014	0.358	0.25	0.446
		2015	0.208	0.129	0.331
		2016	0.232	0.149	0.351
		2017	0.212	0.131	0.331
		2018	0.189	0.134	0.262
		2019	0.156	0.12	0.195
		2020	0.231	0.199	0.263
		2021	0.175	0.108	0.295
	Adult Female Other Mortality	2004	0.109	0.024	0.276
		2005	0.13	0.03	0.295
		2006	0.166	0.04	0.334
		2007	0.132	0.035	0.266
		2008	0.095	0.029	0.194
		2009	0.474	0.123	0.767
		2010	0.341	0.051	0.645
		2011	0.12	0.028	0.314
		2012	0.1	0.024	0.231
		2013	0.111	0.025	0.261
		2014	0.19	0.038	0.478
		2015	0.185	0.043	0.462
		2016	0.164	0.04	0.389
		2017	0.156	0.043	0.338
		2018	0.093	0.023	0.222
		2019	0.136	0.038	0.297
		2020	0.187	0.126	0.248
		2021	0.119	0.067	0.173
	Adult Male Other Mortality	2004	0.196	0.037	0.44
		2005	0.181	0.039	0.417
		2006	0.201	0.051	0.399

HD	Vital Rate	Year	Mean	LCL	UCL
		2007	0.182	0.05	0.383
		2008	0.194	0.056	0.392
		2009	0.324	0.12	0.501
		2010	0.324	0.098	0.613
		2011	0.219	0.069	0.436
		2012	0.253	0.084	0.474
		2013	0.587	0.321	0.77
		2014	0.315	0.094	0.559
		2015	0.357	0.092	0.675
		2016	0.336	0.09	0.647
		2017	0.277	0.071	0.612
		2018	0.204	0.059	0.414
		2019	0.192	0.058	0.397
		2020	0.366	0.076	0.662
		2021	0.278	0.065	0.617
	Recruitment	2005	0.991	0.486	1.796
		2006	0.76	0.683	0.863
		2007	0.647	0.222	1.155
		2008	0.162	0.109	0.27
		2009	1.282	1.028	1.592
		2010	0.57	0.338	0.939
		2011	0.15	0.09	0.226
		2012	0.351	0.23	0.513
		2013	0.521	0.329	0.772
		2014	1.185	0.76	1.666
		2015	0.903	0.615	1.338
		2016	0.84	0.53	1.37
		2017	1.058	0.719	1.543
		2018	0.636	0.375	0.963
		2019	0.508	0.388	0.661
		2020	0.431	0.385	0.485
		2021	0.238	0.177	0.311
	lambda	2005	1.046	0.849	1.299
		2006	0.938	0.834	1.037
		2007	0.879	0.74	1.019
		2008	0.674	0.591	0.76
		2009	1.48	1.315	1.659
		2010	0.707	0.564	0.886
		2011	0.657	0.481	0.821
		2012	0.952	0.795	1.072
		2013	1.067	0.936	1.209
		2014	1.368	1.092	1.671
		2015	1.141	0.938	1.362
		2016	1.101	0.914	1.315
		2017	1.221	1.022	1.438
		2018	1.03	0.887	1.181
		2019	1.046	0.931	1.159
		2020	0.989	0.869	1.073
		2021	0.786	0.69	0.881
620	Adult Female Survival	2004	0.821	0.734	0.886
		2005	0.805	0.708	0.875
		2006	0.803	0.685	0.884
		2007	0.64	0.517	0.741
		2008	0.674	0.527	0.785
		2009	0.562	0.409	0.711
		2010	0.522	0.37	0.662
		2011	0.726	0.585	0.831
		2012	0.774	0.645	0.867
		2013	0.772	0.632	0.872
		2014	0.733	0.597	0.834
		2015	0.722	0.584	0.827

HD	Vital Rate	Year	Mean	LCL	UCL
		2016	0.758	0.623	0.855
		2017	0.781	0.654	0.87
		2018	0.837	0.728	0.912
		2019	0.82	0.695	0.903
		2020	0.724	0.636	0.807
		2021	0.849	0.801	0.893
	Adult Male Survival	2004	0.541	0.379	0.671
		2005	0.531	0.407	0.639
		2006	0.459	0.353	0.555
		2007	0.243	0.136	0.362
		2008	0.461	0.344	0.564
		2009	0.45	0.364	0.527
		2010	0.343	0.249	0.433
		2011	0.491	0.391	0.584
		2012	0.359	0.231	0.48
		2013	0.399	0.265	0.522
		2014	0.156	0.074	0.26
		2015	0.318	0.194	0.443
		2016	0.303	0.178	0.428
		2017	0.239	0.126	0.364
		2018	0.435	0.284	0.573
		2019	0.368	0.225	0.513
		2020	0.264	0.14	0.401
		2021	0.343	0.203	0.483
	Juvenile Female Survival	2004	0.733	0.549	0.871
		2005	0.73	0.549	0.868
		2006	0.721	0.532	0.865
		2007	0.688	0.497	0.845
		2008	0.642	0.432	0.82
		2009	0.66	0.449	0.837
		2010	0.668	0.458	0.838
		2011	0.705	0.507	0.858
		2012	0.701	0.511	0.854
		2013	0.704	0.508	0.857
		2014	0.673	0.468	0.841
		2015	0.683	0.485	0.844
		2016	0.678	0.47	0.842
		2017	0.684	0.482	0.845
		2018	0.707	0.51	0.857
		2019	0.702	0.509	0.856
		2020	0.712	0.52	0.861
		2021	0.719	0.526	0.864
	Juvenile Male Survival	2004	0.769	0.611	0.885
		2005	0.774	0.613	0.889
		2006	0.779	0.628	0.891
		2007	0.795	0.66	0.895
		2008	0.789	0.654	0.892
		2009	0.768	0.615	0.885
		2010	0.768	0.607	0.886
		2011	0.741	0.561	0.874
		2012	0.778	0.622	0.89
		2013	0.789	0.642	0.895
		2014	0.761	0.609	0.878
		2015	0.751	0.587	0.876
		2016	0.757	0.6	0.878
		2017	0.735	0.56	0.869
		2018	0.753	0.588	0.879
		2019	0.744	0.589	0.871
		2020	0.728	0.555	0.863
		2021	0.728	0.543	0.867
	Adult Female Harvest Rate	2004	0.038	0.028	0.051

HD	Vital Rate	Year	Mean	LCL	UCL
		2005	0.042	0.032	0.053
		2006	0.038	0.029	0.05
		2007	0.144	0.118	0.175
		2008	0.102	0.08	0.128
		2009	0.106	0.084	0.135
		2010	0.149	0.116	0.19
		2011	0.053	0.037	0.073
		2012	0.039	0.026	0.056
		2013	0.042	0.027	0.06
		2014	0.067	0.046	0.093
		2015	0.069	0.049	0.095
		2016	0.053	0.037	0.075
		2017	0.046	0.032	0.065
		2018	0.025	0.016	0.037
		2019	0.029	0.019	0.042
		2020	0.042	0.03	0.059
		2021	0.038	0.027	0.052
	Adult Male Harvest Rate	2004	0.231	0.163	0.34
		2005	0.239	0.185	0.305
		2006	0.334	0.28	0.393
		2007	0.573	0.455	0.698
		2008	0.334	0.274	0.405
		2009	0.375	0.321	0.434
		2010	0.483	0.411	0.567
		2011	0.306	0.243	0.38
		2012	0.432	0.329	0.556
		2013	0.38	0.282	0.5
		2014	0.683	0.556	0.803
		2015	0.459	0.356	0.58
		2016	0.48	0.372	0.612
		2017	0.559	0.437	0.694
		2018	0.29	0.204	0.404
		2019	0.345	0.252	0.462
		2020	0.533	0.4	0.683
		2021	0.44	0.326	0.582
	Adult Female Other Mortality	2004	0.14	0.077	0.226
		2005	0.154	0.084	0.25
		2006	0.159	0.078	0.277
		2007	0.216	0.118	0.339
		2008	0.225	0.116	0.373
		2009	0.331	0.174	0.494
		2010	0.329	0.182	0.492
		2011	0.222	0.118	0.365
		2012	0.186	0.097	0.314
		2013	0.186	0.09	0.326
		2014	0.2	0.105	0.331
		2015	0.209	0.109	0.343
		2016	0.189	0.098	0.319
		2017	0.173	0.088	0.295
		2018	0.138	0.066	0.245
		2019	0.151	0.071	0.274
		2020	0.234	0.152	0.32
		2021	0.112	0.072	0.159
	Adult Male Other Mortality	2004	0.228	0.13	0.35
		2005	0.23	0.134	0.349
		2006	0.207	0.125	0.31
		2007	0.184	0.109	0.276
		2008	0.205	0.12	0.312
		2009	0.176	0.105	0.265
		2010	0.174	0.105	0.262
		2011	0.203	0.127	0.296

HD	Vital Rate	Year	Mean	LCL	UCL
		2012	0.209	0.129	0.306
		2013	0.221	0.136	0.325
		2014	0.161	0.095	0.244
		2015	0.223	0.137	0.328
		2016	0.217	0.132	0.317
		2017	0.203	0.123	0.301
		2018	0.276	0.165	0.408
		2019	0.287	0.169	0.421
		2020	0.203	0.118	0.306
		2021	0.217	0.126	0.329
	Recruitment	2005	0.729	0.613	0.855
		2006	0.561	0.369	0.82
		2007	1.313	1.061	1.632
		2008	1.111	0.805	1.504
		2009	0.44	0.338	0.575
		2010	0.432	0.302	0.599
		2011	0.226	0.141	0.34
		2012	0.48	0.312	0.713
		2013	0.483	0.311	0.707
		2014	1.149	0.801	1.604
		2015	0.782	0.555	1.09
		2016	0.859	0.571	1.248
		2017	0.859	0.597	1.214
		2018	0.598	0.355	0.921
		2019	1.133	0.816	1.534
		2020	1.065	0.697	1.563
		2021	0.437	0.294	0.621
	lambda	2005	1.1	1.003	1.198
		2006	0.99	0.899	1.092
		2007	1.334	1.195	1.474
		2008	1.053	0.936	1.177
		2009	0.809	0.732	0.882
		2010	0.694	0.6	0.787
		2011	0.567	0.485	0.644
		2012	0.856	0.751	0.953
		2013	0.894	0.794	0.995
		2014	1.27	1.115	1.443
		2015	0.984	0.871	1.109
		2016	1.022	0.897	1.16
		2017	1.047	0.915	1.192
		2018	0.926	0.809	1.058
		2019	1.33	1.155	1.537
		2020	1.226	1.054	1.446
		2021	0.832	0.742	0.924
701	Adult Female Survival	2004	0.597	0.483	0.701
		2005	0.654	0.541	0.746
		2006	0.623	0.525	0.712
		2007	0.601	0.501	0.676
		2008	0.634	0.531	0.721
		2009	0.578	0.456	0.672
		2010	0.689	0.524	0.805
		2011	0.751	0.625	0.845
		2012	0.804	0.678	0.894
		2013	0.77	0.63	0.874
		2014	0.776	0.62	0.885
		2015	0.773	0.635	0.875
		2016	0.695	0.554	0.805
		2017	0.749	0.616	0.847
		2018	0.777	0.678	0.857
		2019	0.737	0.605	0.829
		2020	0.746	0.682	0.805

HD	Vital Rate	Year	Mean	LCL	UCL
		2021	0.85	0.808	0.889
	Adult Male Survival	2004	0.361	0.239	0.477
		2005	0.448	0.323	0.557
		2006	0.383	0.28	0.488
		2007	0.39	0.276	0.494
		2008	0.373	0.268	0.473
		2009	0.275	0.17	0.376
		2010	0.268	0.167	0.365
		2011	0.364	0.238	0.485
		2012	0.426	0.282	0.564
		2013	0.517	0.353	0.661
		2014	0.411	0.264	0.555
		2015	0.428	0.29	0.556
		2016	0.246	0.134	0.366
		2017	0.365	0.229	0.493
		2018	0.364	0.251	0.471
		2019	0.244	0.126	0.369
		2020	0.3	0.178	0.425
		2021	0.268	0.153	0.387
	Juvenile Female Survival	2004	0.684	0.496	0.846
		2005	0.693	0.501	0.852
		2006	0.674	0.464	0.842
		2007	0.684	0.491	0.841
		2008	0.686	0.486	0.848
		2009	0.676	0.478	0.84
		2010	0.699	0.501	0.856
		2011	0.707	0.516	0.859
		2012	0.697	0.499	0.854
		2013	0.71	0.517	0.861
		2014	0.699	0.499	0.854
		2015	0.697	0.493	0.856
		2016	0.691	0.494	0.853
		2017	0.698	0.507	0.852
		2018	0.708	0.509	0.858
		2019	0.692	0.493	0.846
		2020	0.705	0.5	0.86
		2021	0.714	0.521	0.862
	Juvenile Male Survival	2004	0.701	0.511	0.851
		2005	0.714	0.522	0.861
		2006	0.708	0.528	0.85
		2007	0.718	0.537	0.869
		2008	0.75	0.577	0.879
		2009	0.776	0.628	0.886
		2010	0.731	0.554	0.868
		2011	0.707	0.509	0.859
		2012	0.697	0.493	0.855
		2013	0.721	0.531	0.866
		2014	0.725	0.542	0.866
		2015	0.736	0.562	0.869
		2016	0.724	0.544	0.863
		2017	0.752	0.588	0.876
		2018	0.744	0.571	0.875
		2019	0.779	0.645	0.888
		2020	0.762	0.6	0.882
		2021	0.714	0.519	0.862
	Adult Female Harvest Rate	2004	0.167	0.14	0.2
		2005	0.141	0.115	0.169
		2006	0.201	0.163	0.244
		2007	0.239	0.197	0.283
		2008	0.188	0.152	0.228
		2009	0.229	0.184	0.274

HD	Vital Rate	Year	Mean	LCL	UCL
		2010	0.097	0.077	0.12
		2011	0.037	0.029	0.048
		2012	0.013	0.009	0.018
		2013	0.017	0.012	0.023
		2014	0.016	0.011	0.023
		2015	0.028	0.02	0.037
		2016	0.077	0.059	0.1
		2017	0.052	0.039	0.067
		2018	0.052	0.04	0.066
		2019	0.072	0.056	0.09
		2020	0.068	0.053	0.085
		2021	0.043	0.033	0.055
	Adult Male Harvest Rate	2004	0.35	0.279	0.447
		2005	0.305	0.244	0.386
		2006	0.382	0.322	0.462
		2007	0.364	0.296	0.455
		2008	0.395	0.326	0.486
		2009	0.516	0.433	0.624
		2010	0.53	0.446	0.633
		2011	0.373	0.29	0.488
		2012	0.27	0.194	0.372
		2013	0.192	0.138	0.263
		2014	0.274	0.197	0.373
		2015	0.299	0.23	0.387
		2016	0.546	0.427	0.677
		2017	0.406	0.311	0.528
		2018	0.433	0.347	0.541
		2019	0.573	0.446	0.721
		2020	0.48	0.381	0.602
		2021	0.533	0.414	0.673
	Adult Female Other Mortality	2004	0.236	0.133	0.357
		2005	0.205	0.114	0.33
		2006	0.176	0.092	0.282
		2007	0.16	0.083	0.277
		2008	0.177	0.094	0.284
		2009	0.193	0.097	0.325
		2010	0.214	0.095	0.387
		2011	0.211	0.117	0.338
		2012	0.183	0.093	0.309
		2013	0.213	0.11	0.353
		2014	0.208	0.099	0.363
		2015	0.199	0.099	0.336
		2016	0.228	0.121	0.369
		2017	0.2	0.103	0.332
		2018	0.172	0.093	0.27
		2019	0.191	0.101	0.323
		2020	0.186	0.128	0.249
		2021	0.107	0.07	0.148
	Adult Male Other Mortality	2004	0.289	0.17	0.419
		2005	0.248	0.144	0.368
		2006	0.235	0.142	0.339
		2007	0.245	0.145	0.362
		2008	0.232	0.139	0.346
		2009	0.208	0.129	0.306
		2010	0.202	0.125	0.292
		2011	0.263	0.163	0.381
		2012	0.304	0.184	0.442
		2013	0.291	0.162	0.449
		2014	0.315	0.184	0.464
		2015	0.273	0.164	0.403
		2016	0.208	0.128	0.307

HD	Vital Rate	Year	Mean	LCL	UCL
		2017	0.23	0.138	0.343
		2018	0.203	0.121	0.301
		2019	0.183	0.104	0.28
		2020	0.22	0.128	0.331
		2021	0.2	0.115	0.302
	Recruitment	2005	0.844	0.764	0.938
		2006	1.027	0.721	1.398
		2007	0.584	0.483	0.705
		2008	0.658	0.481	0.858
		2009	0.823	0.666	1.021
		2010	0.466	0.33	0.637
		2011	0.325	0.238	0.453
		2012	0.467	0.335	0.629
		2013	0.319	0.235	0.44
		2014	0.877	0.618	1.206
		2015	0.719	0.538	0.963
		2016	0.942	0.693	1.271
		2017	0.893	0.658	1.194
		2018	0.415	0.286	0.589
		2019	1.12	0.848	1.455
		2020	0.572	0.378	0.843
		2021	0.421	0.312	0.559
	lambda	2005	0.863	0.765	0.965
		2006	1.018	0.898	1.127
		2007	0.804	0.729	0.878
		2008	0.802	0.724	0.872
		2009	0.907	0.832	0.983
		2010	0.726	0.65	0.793
		2011	0.716	0.627	0.788
		2012	0.895	0.794	0.985
		2013	0.888	0.793	0.974
		2014	1.191	1.05	1.335
		2015	1.055	0.939	1.174
		2016	1.14	1.015	1.271
		2017	1.001	0.887	1.113
		2018	0.855	0.769	0.938
		2019	1.208	1.076	1.345
		2020	0.922	0.811	1.042
		2021	0.834	0.767	0.902
705	Adult Female Survival	2004	0.631	0.528	0.714
		2005	0.631	0.522	0.717
		2006	0.572	0.471	0.651
		2007	0.509	0.411	0.591
		2008	0.56	0.452	0.656
		2009	0.58	0.47	0.665
		2010	0.658	0.491	0.804
		2011	0.752	0.631	0.847
		2012	0.765	0.633	0.869
		2013	0.789	0.641	0.891
		2014	0.792	0.65	0.892
		2015	0.792	0.643	0.889
		2016	0.729	0.592	0.83
		2017	0.704	0.57	0.809
		2018	0.754	0.615	0.852
		2019	0.771	0.634	0.866
		2020	0.646	0.574	0.716
		2021	0.835	0.792	0.874
	Adult Male Survival	2004	0.416	0.293	0.535
		2005	0.486	0.352	0.597
		2006	0.368	0.263	0.467
		2007	0.242	0.14	0.348

HD	Vital Rate	Year	Mean	LCL	UCL
		2008	0.331	0.224	0.433
		2009	0.363	0.256	0.463
		2010	0.314	0.203	0.424
		2011	0.373	0.25	0.487
		2012	0.39	0.258	0.517
		2013	0.38	0.241	0.516
		2014	0.436	0.291	0.564
		2015	0.362	0.235	0.485
		2016	0.272	0.161	0.386
		2017	0.211	0.113	0.325
		2018	0.272	0.153	0.393
		2019	0.352	0.225	0.485
		2020	0.328	0.201	0.454
		2021	0.386	0.248	0.525
	Juvenile Female Survival	2004	0.71	0.519	0.858
		2005	0.701	0.496	0.861
		2006	0.695	0.497	0.847
		2007	0.692	0.499	0.848
		2008	0.664	0.464	0.832
		2009	0.689	0.488	0.846
		2010	0.68	0.484	0.843
		2011	0.708	0.515	0.861
		2012	0.711	0.521	0.861
		2013	0.703	0.503	0.854
		2014	0.709	0.508	0.861
		2015	0.708	0.512	0.857
		2016	0.69	0.49	0.845
		2017	0.677	0.477	0.843
		2018	0.667	0.456	0.835
		2019	0.663	0.444	0.83
		2020	0.691	0.5	0.848
		2021	0.713	0.519	0.862
	Juvenile Male Survival	2004	0.71	0.53	0.859
		2005	0.737	0.555	0.875
		2006	0.763	0.603	0.884
		2007	0.768	0.616	0.883
		2008	0.738	0.565	0.87
		2009	0.718	0.53	0.861
		2010	0.71	0.518	0.86
		2011	0.734	0.555	0.87
		2012	0.744	0.57	0.874
		2013	0.749	0.582	0.873
		2014	0.76	0.599	0.879
		2015	0.776	0.633	0.886
		2016	0.768	0.619	0.883
		2017	0.731	0.563	0.867
		2018	0.706	0.527	0.857
		2019	0.714	0.538	0.86
		2020	0.722	0.541	0.866
		2021	0.72	0.531	0.864
	Adult Female Harvest Rate	2004	0.185	0.148	0.232
		2005	0.176	0.147	0.216
		2006	0.269	0.225	0.335
		2007	0.35	0.298	0.418
		2008	0.268	0.22	0.331
		2009	0.25	0.208	0.295
		2010	0.072	0.057	0.091
		2011	0.036	0.028	0.047
		2012	0.02	0.014	0.027
		2013	0.014	0.009	0.02
		2014	0.012	0.008	0.018

HD	Vital Rate	Year	Mean	LCL	UCL
		2015	0.024	0.017	0.032
		2016	0.058	0.045	0.075
		2017	0.065	0.051	0.083
		2018	0.049	0.038	0.062
		2019	0.047	0.037	0.06
		2020	0.061	0.048	0.076
		2021	0.061	0.047	0.076
	Adult Male Harvest Rate	2004	0.329	0.255	0.431
		2005	0.267	0.209	0.334
		2006	0.41	0.344	0.487
		2007	0.559	0.457	0.674
		2008	0.43	0.359	0.512
		2009	0.382	0.319	0.457
		2010	0.432	0.355	0.524
		2011	0.387	0.306	0.489
		2012	0.363	0.279	0.469
		2013	0.367	0.281	0.474
		2014	0.29	0.225	0.372
		2015	0.393	0.315	0.486
		2016	0.525	0.421	0.643
		2017	0.594	0.483	0.719
		2018	0.505	0.402	0.631
		2019	0.416	0.322	0.53
		2020	0.427	0.337	0.543
		2021	0.353	0.266	0.466
	Adult Female Other Mortality	2004	0.184	0.102	0.292
		2005	0.193	0.108	0.307
		2006	0.159	0.087	0.264
		2007	0.141	0.073	0.234
		2008	0.172	0.089	0.287
		2009	0.17	0.091	0.286
		2010	0.27	0.119	0.444
		2011	0.211	0.117	0.332
		2012	0.215	0.111	0.347
		2013	0.197	0.097	0.344
		2014	0.196	0.096	0.338
		2015	0.185	0.088	0.331
		2016	0.213	0.113	0.349
		2017	0.231	0.127	0.365
		2018	0.197	0.102	0.335
		2019	0.182	0.09	0.317
		2020	0.293	0.224	0.365
		2021	0.104	0.068	0.144
	Adult Male Other Mortality	2004	0.255	0.154	0.372
		2005	0.247	0.143	0.377
		2006	0.221	0.133	0.327
		2007	0.199	0.12	0.29
		2008	0.239	0.15	0.346
		2009	0.256	0.154	0.373
		2010	0.254	0.157	0.367
		2011	0.24	0.147	0.354
		2012	0.247	0.144	0.366
		2013	0.252	0.147	0.378
		2014	0.274	0.158	0.413
		2015	0.245	0.148	0.359
		2016	0.202	0.124	0.293
		2017	0.195	0.117	0.289
		2018	0.223	0.133	0.33
		2019	0.232	0.135	0.348
		2020	0.245	0.137	0.367
		2021	0.261	0.149	0.391

HD	Vital Rate	Year	Mean	LCL	UCL
	Recruitment	2005	0.916	0.783	1.067
		2006	0.946	0.673	1.36
		2007	1.294	1.051	1.571
		2008	1.211	0.904	1.64
		2009	0.675	0.54	0.831
		2010	0.694	0.5	0.928
		2011	0.446	0.324	0.598
		2012	0.579	0.435	0.756
		2013	0.969	0.742	1.266
		2014	0.957	0.69	1.278
		2015	1.122	0.869	1.43
		2016	0.963	0.694	1.288
		2017	1.408	1.074	1.827
		2018	1.278	0.933	1.761
		2019	1.18	0.903	1.528
		2020	0.706	0.517	0.963
		2021	0.364	0.271	0.481
	lambda	2005	0.929	0.836	1.019
		2006	0.965	0.862	1.077
		2007	1.007	0.902	1.107
		2008	0.924	0.839	1.017
		2009	0.778	0.709	0.846
		2010	0.777	0.704	0.853
		2011	0.746	0.659	0.83
		2012	0.92	0.83	1.005
		2013	1.159	1.035	1.298
		2014	1.157	1.036	1.283
		2015	1.227	1.091	1.379
		2016	1.125	1.011	1.242
		2017	1.231	1.088	1.369
		2018	1.14	0.991	1.303
		2019	1.129	0.994	1.267
		2020	0.959	0.856	1.069
		2021	0.734	0.667	0.8