



# Migration Matters

The migratory journeys of mule deer in Oregon



Oregon Department of Fish and Wildlife



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Photo Credit: Keith Kohl



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**Oregon Department of Fish and Wildlife**



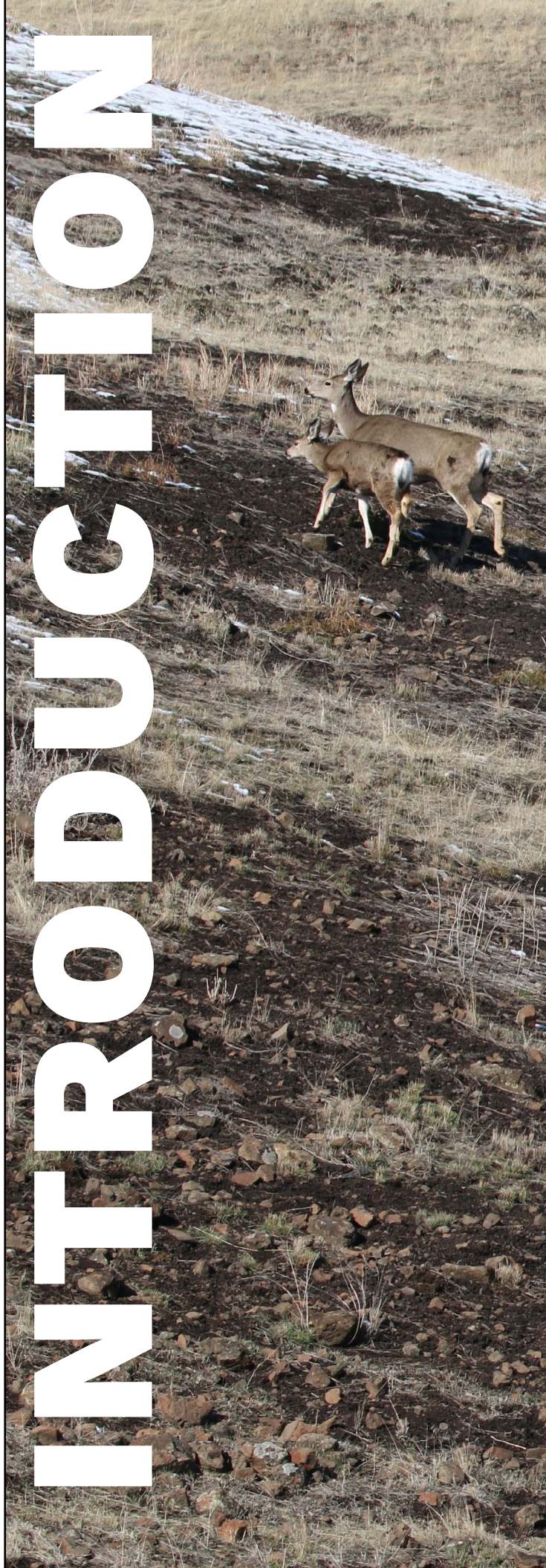
**THE STORY OF MULE DEER MIGRATION IS A STORY OF WESTERN LANDS.** Over thousands of years, mule deer have learned to navigate these complex landscapes and their dynamic climates. Each spring, many mule deer migrate to take advantage of rich vegetation, following the growth of young, nutritious plants to higher elevations <sup>1, 2</sup> and escaping the dry summer heat of the sage-steppe and mixed juniper woodlands below. They spend their summers feeding on lush grasses, forbs, and shrubs and birthing and raising fawns. Each fall as cold weather moves in, they return to lower elevations, avoiding the worst of the snow. The routes of these remarkable trips have been passed from generation to generation, with fawns following in their mother's footsteps and learning the best paths to travel.<sup>3</sup> Mule deer are an important part of the cultural, conservation, and hunting heritage in the West, and these migrations are critical to sustaining mule deer populations. The landscapes that support these incredible journeys, however, are becoming increasingly difficult for mule deer to navigate.

The habitats that mule deer live in and travel through are being fragmented by roadways, fencing, housing developments, agricultural uses, and energy developments. While migrating deer can often move through disturbed habitats, habitat loss and fragmentation, and their associated barriers to movement, have the potential to diminish the benefits provided by migration and may threaten its persistence.<sup>4</sup> Migration allows mule deer to access the best resources year-round. <sup>5, 6</sup> With increasing pressure on western landscapes for road travel, residential sprawl, recreation, and energy, keeping Oregon's landscape intact and permeable to migrating mule deer is a mounting challenge.

The goal of this story is to provide a glimpse into mule deer migration in Oregon, and the difficulties these animals face during their journeys. The maps and figures presented here illustrate just some of the barriers to movement that mule deer experience. This story is intended to educate, but also to inspire. Through collaboration and cooperation among a wide range of stakeholders, management and conservation efforts can help reduce the impacts of human development on mule deer and help sustain their migrations into the future.

*A herd of mule deer migrates in search of higher-quality forage.*  
Photo Credit: Roblyn Brown

# INTRODUCTION









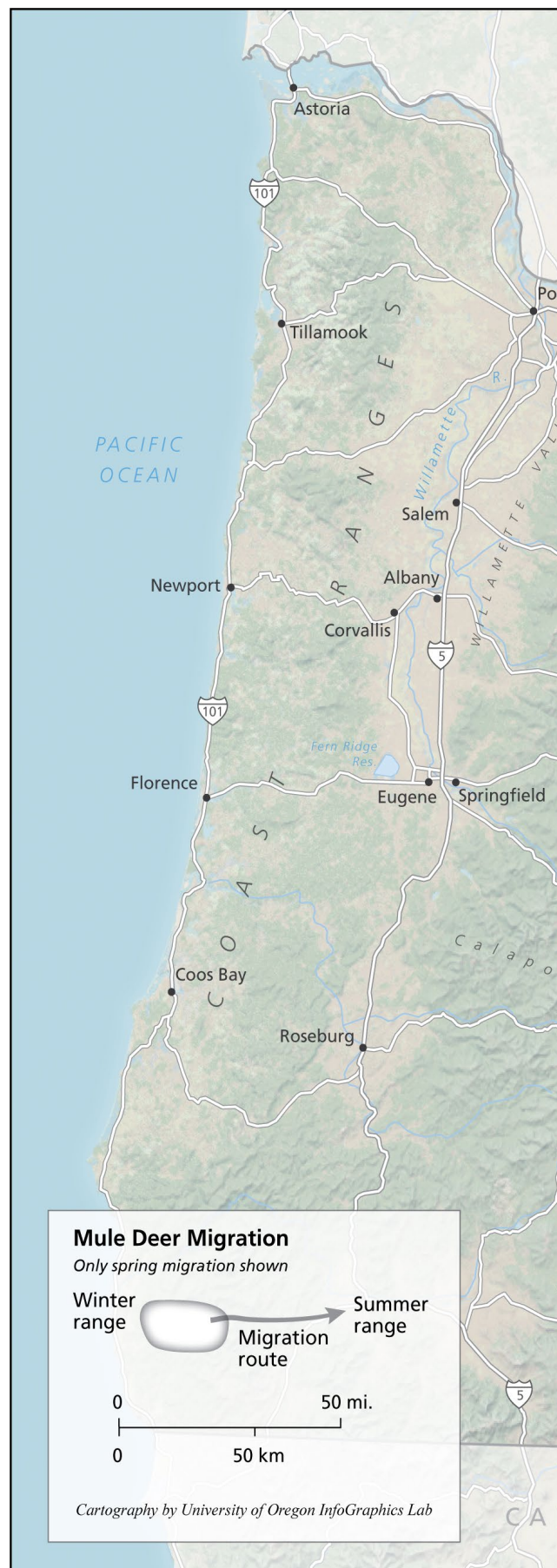
# DEER ON THE MOVE

**MIGRATION ALLOWS MULE DEER TO FOLLOW SEASONAL PEAKS IN FOOD AVAILABILITY ACROSS THE LANDSCAPE** and to escape unfavorable climatic conditions. **5, 7, 8** Across Oregon, more than 60% of mule deer migrate. Along the east slope of the Cascade mountains, where topography and seasonal changes in climate are more extreme, upwards of 98% of mule deer are migratory. Migration confers numerous benefits, including better survival. Here in Oregon, migratory deer have been found to have a 6% higher annual survival rate compared to residents. **9**

Throughout the state, different herds move in different ways (**Map 1**), each having learned over generations the intricacies of the landscape, the locations of the best available food sources, and the best pathways between their summer and winter ranges. Mule deer congregate in the basins of the high desert and Blue Mountains in eastern Oregon during the winter and migrate an average of about 30 miles to reach their summer ranges at higher elevations in the Cascade, Steens, and Blue Mountains. In the south-central and eastern parts of the state many cross into California, Nevada, or Idaho for parts of the year. Deer in the Crescent Herd, in central Oregon, migrate the farthest, with some deer traveling 90 miles from winter to summer range. In contrast, the North-Central Herd has the smallest average migration distance, with some individuals moving only 10 miles between ranges.

Ongoing work in Oregon is helping to refine these herd boundaries and identify the migration routes used by individuals in each herd. Continued study will help fill in gaps in understanding of the mule deer population in Oregon, including the locations and movements of herds in the southeastern part of the state, and which herds in that region may be moving between Oregon and neighboring states.

**Map 1:** Mule deer herds in Oregon and their general migratory pathways. Arrows indicate movement during spring migration.





# Oregon Mule Deer Herds and Migration





# Migration Timing and Duration

Mule deer are intimately familiar with their respective landscapes, and individuals have adapted to the specific conditions where they live. As a result, there is variability in migration throughout the state, both between herds and between different individuals within each herd. By attaching GPS tracking collars to individual animals, biologists can collect information not only on the routes deer take during migration, but also when they migrate and how long it takes them to travel between ranges.

Most deer begin their spring migration in Oregon in April (**Figure 1**), as the weather warms and fresh, green vegetation begins to grow. Some individuals move quickly, reaching their summer range within a couple days. Other individuals take more time, sometimes stopping at choice locations along their routes to rest and forage for a few days before moving on.

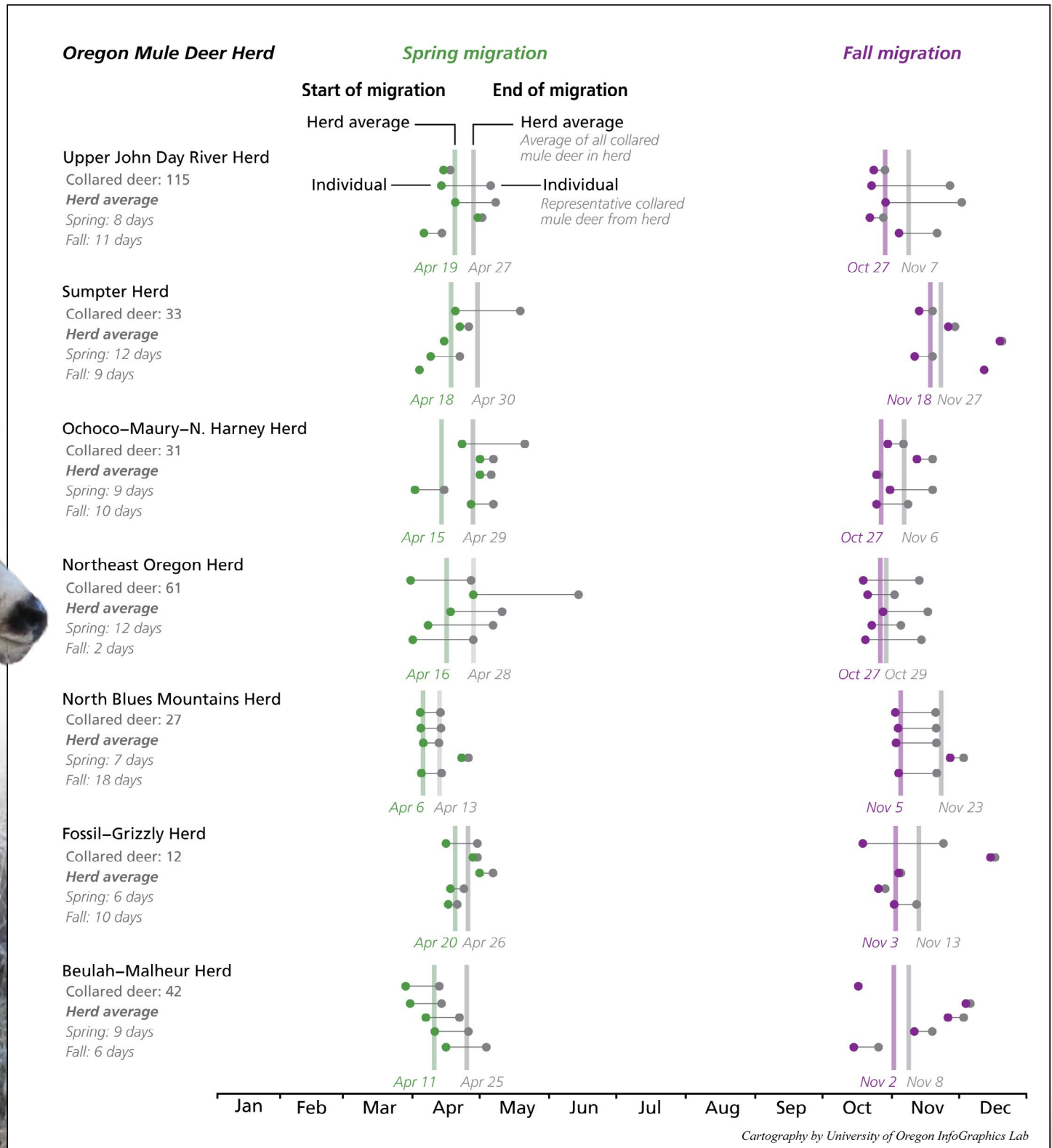
In fall, deer follow their routes in reverse, beginning their travel in October or early November as the weather cools and snow sets in at higher elevations. Here, too, there is variability in the length of time individual deer spend on their routes, with some deer moving quickly back to their winter range and others spending multiple days traveling. This variability in the timing and duration of migration between herds in different geographic regions, and even between individuals within each herd, reflects how intricately mule deer are tied to their environments. Each individual adopts behaviors specific to the landscapes they are in.

*GPS tracking collars, like the one on this mule deer doe, allow biologists to learn more about migration.*  
Photo credit: Roblyn Brown





**Figure 1:** Average timing and duration of migration of collared mule deer from seven of Oregon's mule deer herds. Spring migration generally begins in April, while fall migration usually starts in late October or early November.







# Fidelity

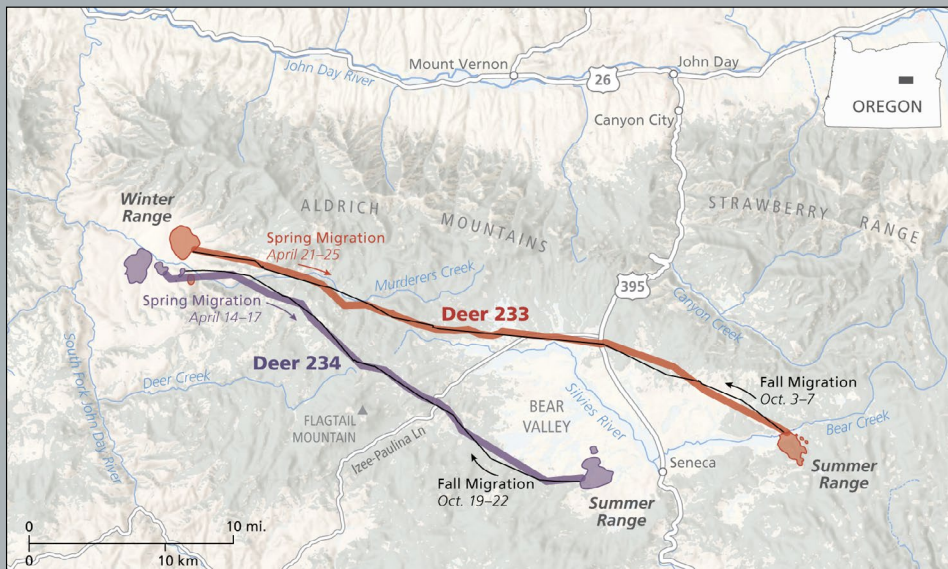
Mule deer in Oregon have very strong fidelity to the areas they use. Not only do migrating deer return to the same summer ranges each spring and the same winter regions each fall, but they also follow the same pathways to trek to and from these ranges, traveling nearly identical routes year after year. Research suggests that migration in deer is not instinctive but is transmitted culturally from parent to offspring. <sup>3</sup> Mule deer learn how to migrate, and which routes to take, from their mother, following closely behind her as she moves to and from her winter and summer ranges.

Biologists tracked the two individuals here, Deer 233 and Deer 234 from the Upper John Day River Herd (**Map 2a-c**), over three consecutive years, illustrating the fidelity of deer to their migratory routes. Note that while the timing of their migratory journeys varies year to year, tracking weather and food availability, the pathways these individuals follow each year hardly vary.

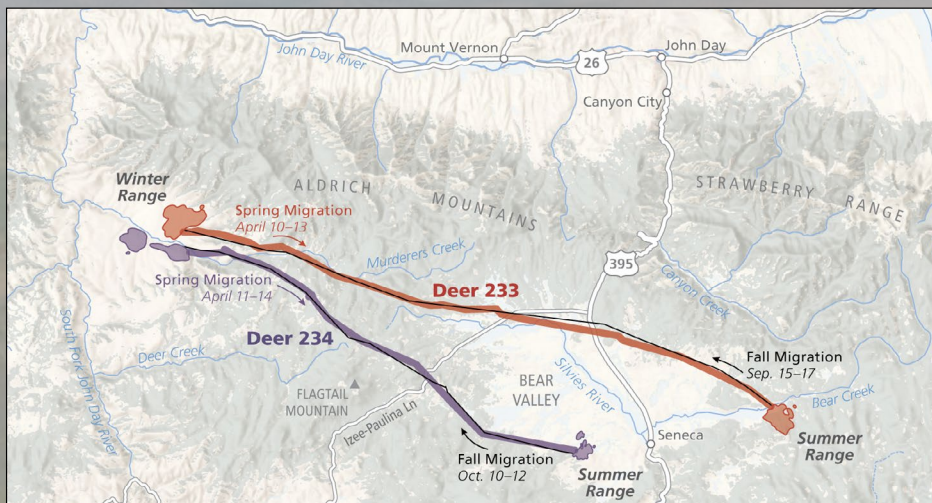
The strong fidelity of mule deer to their migratory routes provides deer with the intimate knowledge needed to navigate the landscape, find food and shelter, and survive the cold, snowy winters and hot, dry summers of the American West, but as these landscapes become increasingly altered by human activities, fidelity comes at a cost. Fidelity of mule deer to their routes can be so high that, even in the face of rapid human development, they do not shift their behavior to identify new, safer routes or discover higher-quality resources. As residential areas expand, as new fences are erected, as traffic increases on roadways, and as new energy facilities are built, it becomes increasingly difficult for mule deer to follow their migratory routes, and the benefits of migration, including access to higher quality forage <sup>6, 10</sup> and, subsequently, higher survival <sup>9</sup> and greater reproductive success <sup>11, 12</sup> are lost.

Photo Credit: (CC BY 2.0) Henry

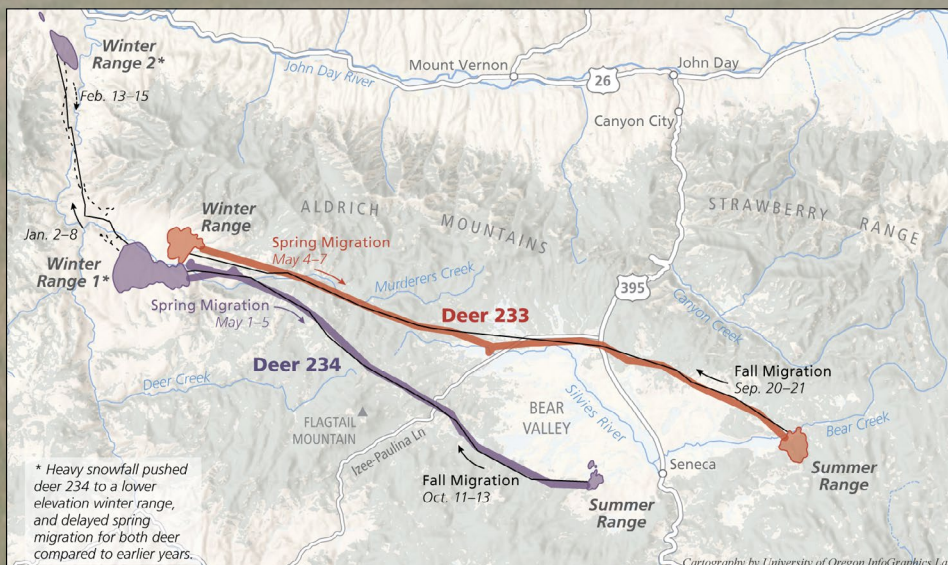




**Map 2a:** Migration pathways of Deer 233 and Deer 234 in 2015. The bold colored lines illustrate their spring migration routes, and the black lines represent their fall migration routes.



**Map 2b:** Migration pathways of Deer 233 and Deer 234 in 2016. Both deer departed from their ranges for migration in spring and fall earlier than in the previous year, but followed the same pathways.



**Map 2c:** Migration pathways of Deer 233 and Deer 234 in 2017. Deer 234 used a slightly different winter range, but both deer follow nearly identical migratory routes year after year.



# BARRIERS

AS HUMAN DEVELOPMENT THROUGHOUT THE WEST INTENSIFIES, so too do the difficulties mule deer face on their migratory journeys. Where once deer could move freely across the landscape, they are now increasingly encountering man-made obstacles that alter their behavior and hinder their travel. In Oregon, two of the most pervasive barriers to mule deer movement are roadways and fences. These features are not merely an inconvenience for deer—crossing roadways and fences comes with a significant mortality risk. One study in south-central Oregon found that, of mule deer deaths with known causes, 30% were a result of deer-vehicle collisions or fence entanglement. <sup>9</sup>

## Roadways

The Federal Highway Administration estimates there are nearly 162,000 miles of roads in Oregon, crisscrossing throughout the state and fragmenting wildlife habitat. The loud noises, bright lights, and unusual smells of roadways can deter deer from approaching, but during migration, as deer faithfully follow their migratory routes, they have no choice but to cross in order to access the food and shelter they need to survive. Many individuals face dozens of road crossings during migration. On roads with high traffic volumes, low visibility, or inattentive drivers, this can spell disaster for both deer and people.

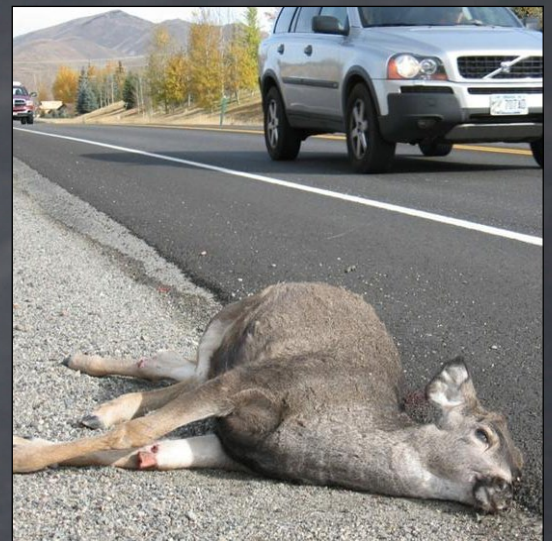
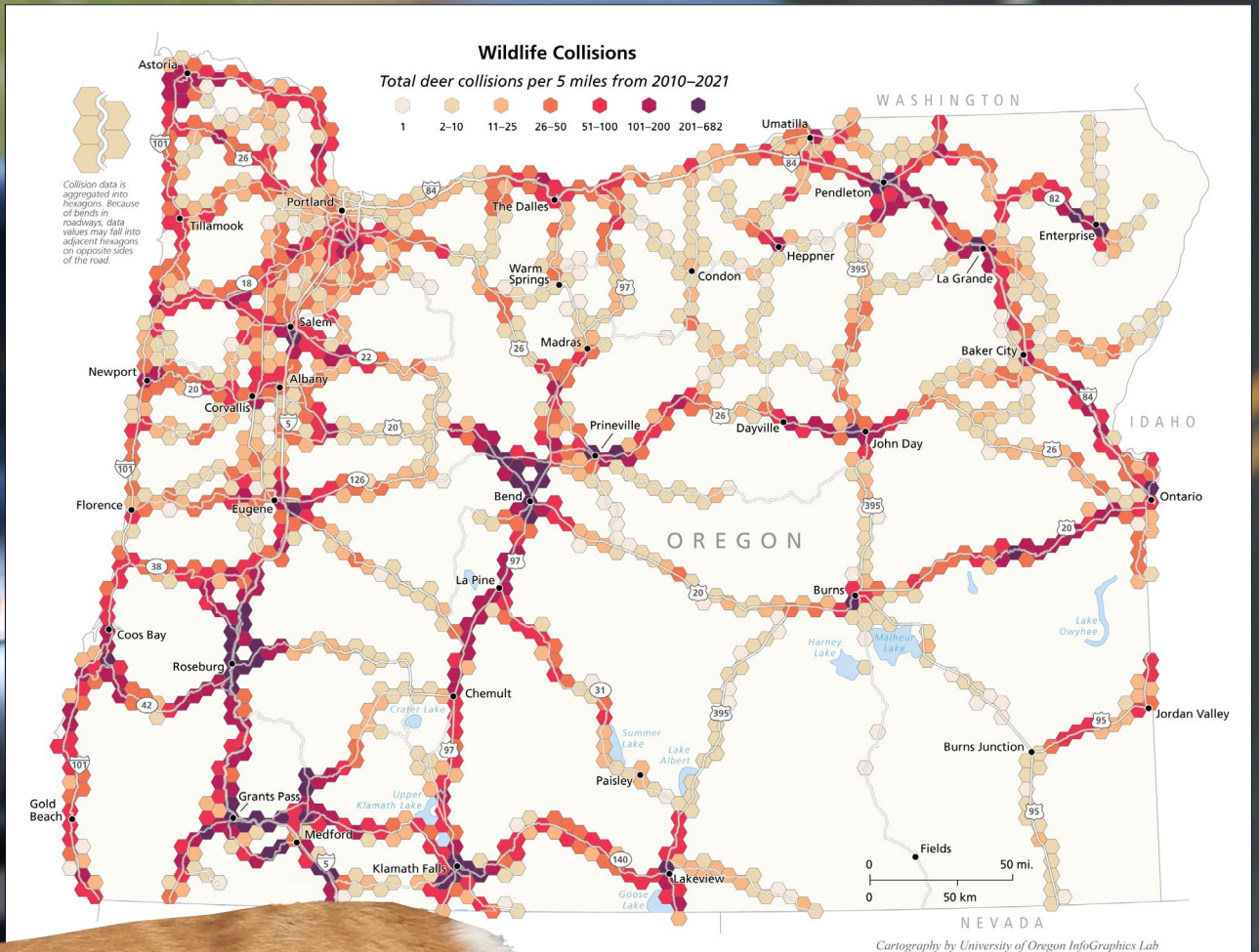
Each year the Oregon Department of Transportation removes an average of nearly 6,000 carcasses of deer struck and killed by vehicles from Oregon's public roadways (**Map 3**). The actual toll of roads on Oregon's deer is much higher—this number does not include deer injured by vehicles that die outside of the road corridor, or deer struck and killed on county, city, or privately-maintained roads. These collisions are costly for people, too. It is estimated that each deer-vehicle collision costs an average of more than \$8,000 in emergency response, towing, vehicle repairs, and medical expenses. <sup>13</sup>

*A mule deer buck crosses the road in front of oncoming traffic. Collisions with deer can be costly and dangerous for motorists.*  
Photo Credit: Roblyn Brown





**Map 3: Number of deer-vehicle collisions per 5 miles between 2010 and 2021 in Oregon.** Many areas of the state see high densities of collisions with deer.

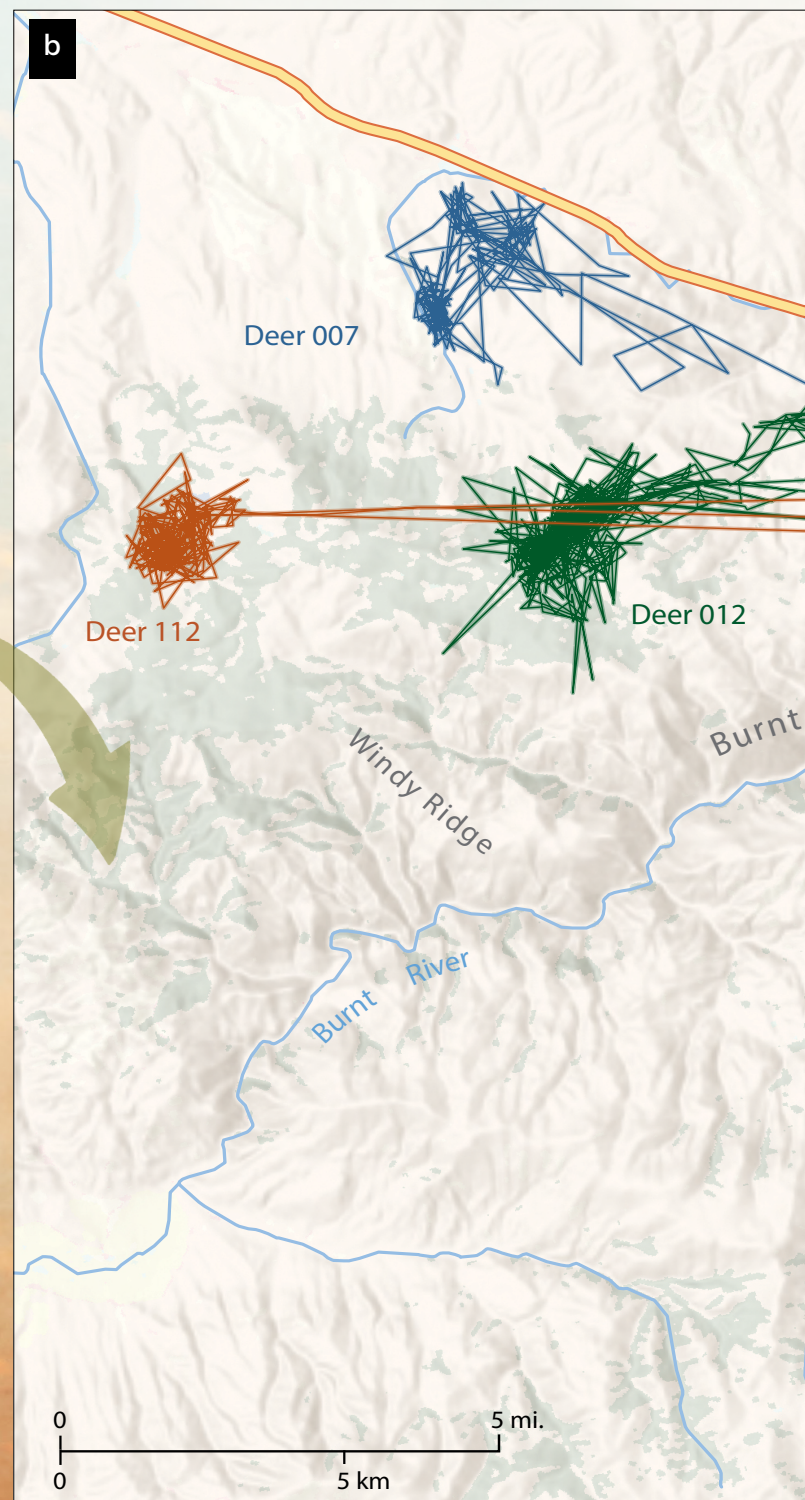
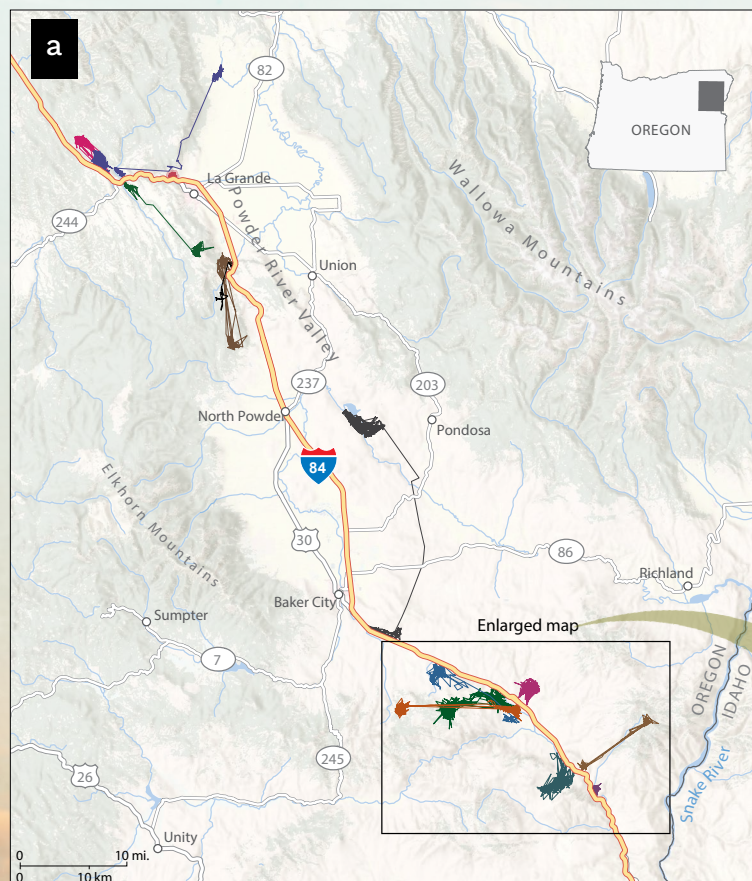


**Vehicle collisions with deer often result in injury or mortality.**  
Photo Credit: Idaho Department of Fish and Game



**AS TRAFFIC VOLUMES INCREASE AND NEW ROADS ARE BUILT TO ACCOMMODATE OREGON'S GROWING POPULATION,** the risk to mule deer of being struck by a vehicle intensifies. At a certain point, roads can become so busy that deer can no longer get across without facing certain death. These roadways then become a complete barrier to mule deer movement, severing historic migration routes, separating groups, and cutting off deer from their former seasonal ranges entirely.

Nowhere is the complete barrier effect of high-traffic-volume roads more apparent than along Interstate highways. Regions bisected by Interstate 84 in Oregon may once have served as functional migratory habitat for mule deer, allowing the movement of individuals to and from their winter and summer ranges. Now, however, the width of the roadway, the number of lanes, the high traffic volumes, and right-of-way fencing mean that deer no longer even attempt to cross—and if they do, they are nearly guaranteed to die trying.

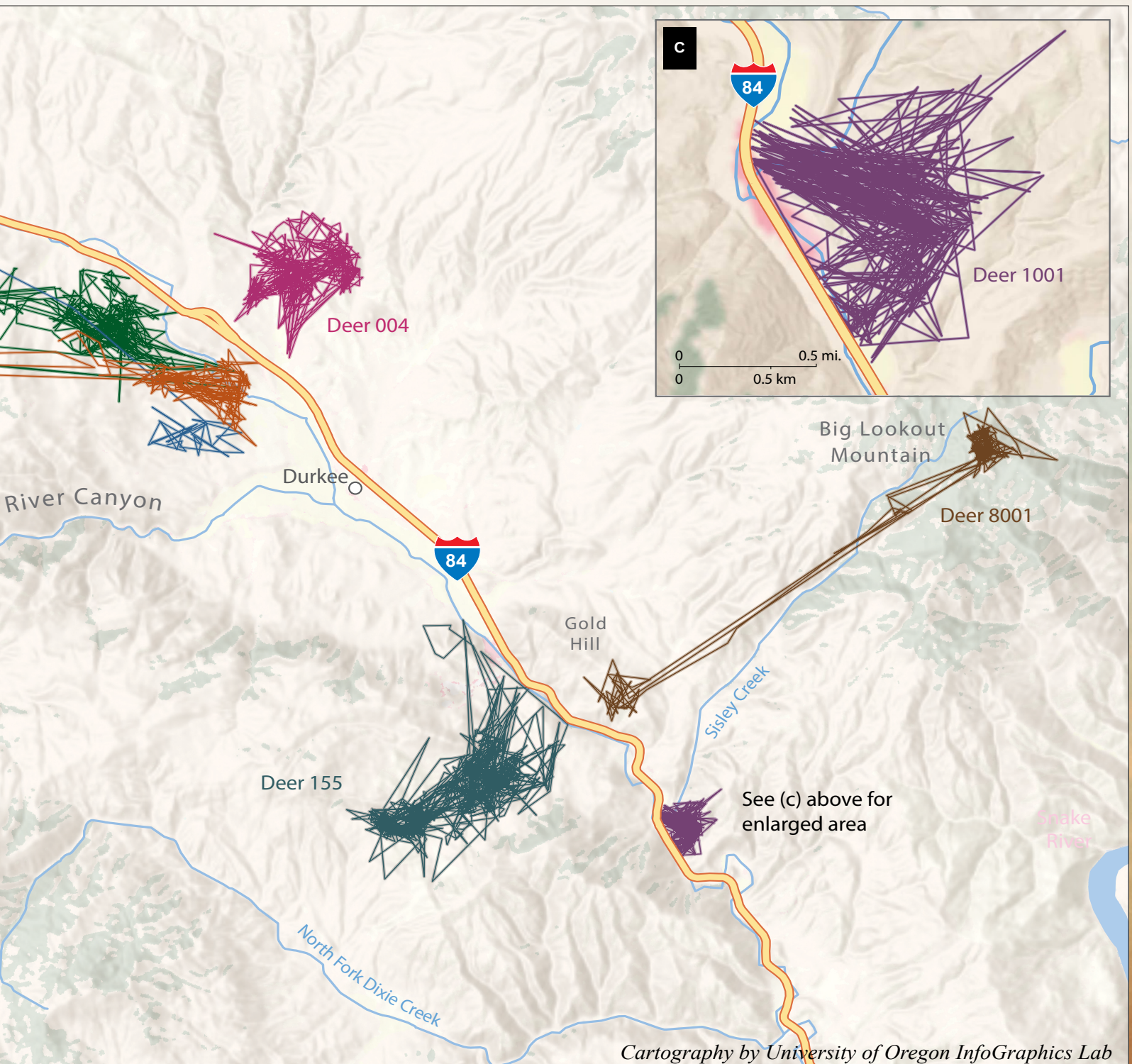


**Map 4a-c:** GPS tracking data of mule deer collared in the Powder River Valley illustrate the barrier effect of Interstate 84. Deer approach but are unable to cross the Interstate, and are separated from individuals on the other side.



Movements of mule deer tracked by biologists along the I-84 corridor in northeast Oregon's Powder River Valley are clearly blocked by the interstate (**Map 4a-c**). The GPS tracks of many deer indicate that they regularly approach I-84 but are turned away. Many encounter I-84 during migration but are unable to cross, spending their time traveling along the roadside trying, and failing, to find safe passage.

One study of mule deer migration in Oregon found that when annual average daily traffic on a roadway exceeds 8,000 vehicles per day, fewer deer will attempt to cross, **14** with individuals instead abandoning migration. Sections of many highways throughout the state are set to meet or exceed this threshold within coming years, meaning that, without mitigation, an increasing number of Oregon's roadways will become barriers to mule deer migration.





# Fences

Even more ubiquitous across western lands than roadways, fencing, in all shapes and sizes, divides the landscape. It is estimated that there are more than 600,000 miles of fences in the western United States, without including urban and suburban property fences.<sup>15</sup> Fencing is so pervasive that the average distance from any given point in the West to the nearest fence is less than two miles,<sup>15</sup> and is likely even shorter, as many fences are undocumented and unmapped. <sup>16</sup> Some fences are placed to intentionally benefit wildlife (e.g., wildlife exclusionary fencing to reduce road mortality and funnel wildlife to road crossing structures), but the vast majority of fencing has negative impacts on wildlife.

The permeability of fencing to mule deer depends on the type, height, and condition of the fence. Some types of fencing, including chain-link, are impassable for deer at heights of 8 feet or greater, and for smaller wildlife at any height, prohibiting access to habitat entirely. Woven wire fencing, often used to contain sheep, is generally shorter in stature, but can separate fawns from their mothers, as fawns are not large enough to jump over them. Barbed wire fences are more passable but carry risks, as deer can become entangled in the wires as they jump over fencing or can suffer injury or hair loss when crawling under.

Mule deer are particularly susceptible to fence effects during migration, as fences directly block their movement paths. In one study of GPS-tracked mule deer in Wyoming, deer altered their behavior at almost half of the fences they encountered, moving away from fences, or pacing back and forth along them if they could not find a place to quickly cross. <sup>17</sup> Fence entanglement is not uncommon, particularly for juveniles. Research on fence entanglements in Colorado and Utah found an annual average of one mule deer death due to entanglement for every ~10 miles of fence. <sup>18</sup>

In Oregon, most fencing is not mapped. Even so, the limited data available illustrates that mule deer must cross fences numerous times during migration (**Map 5**). Biologists tracked the eight individuals pictured here, from the Beulah-Malheur Herd in eastern Oregon, on their spring migrations between winter range in and around land managed by the Bureau of Land Management (BLM) and summer range in the Blue Mountains region. This single dataset of locations of select fences on BLM-managed lands illustrates the minimum number of fence crossings each individual faces during migration—it is likely that the true number of fence crossings is much higher, as the BLM dataset is incomplete and there is no information available on the locations of fences on private lands or lands managed by the U.S. Forest Service. Nevertheless, each of these fence crossings represents an impediment to mule deer migration and an opportunity for injury or mortality.

*A mule deer buck anxiously paces a fence line, looking for a place to cross.*  
Photo Credit: Roblyn Brown

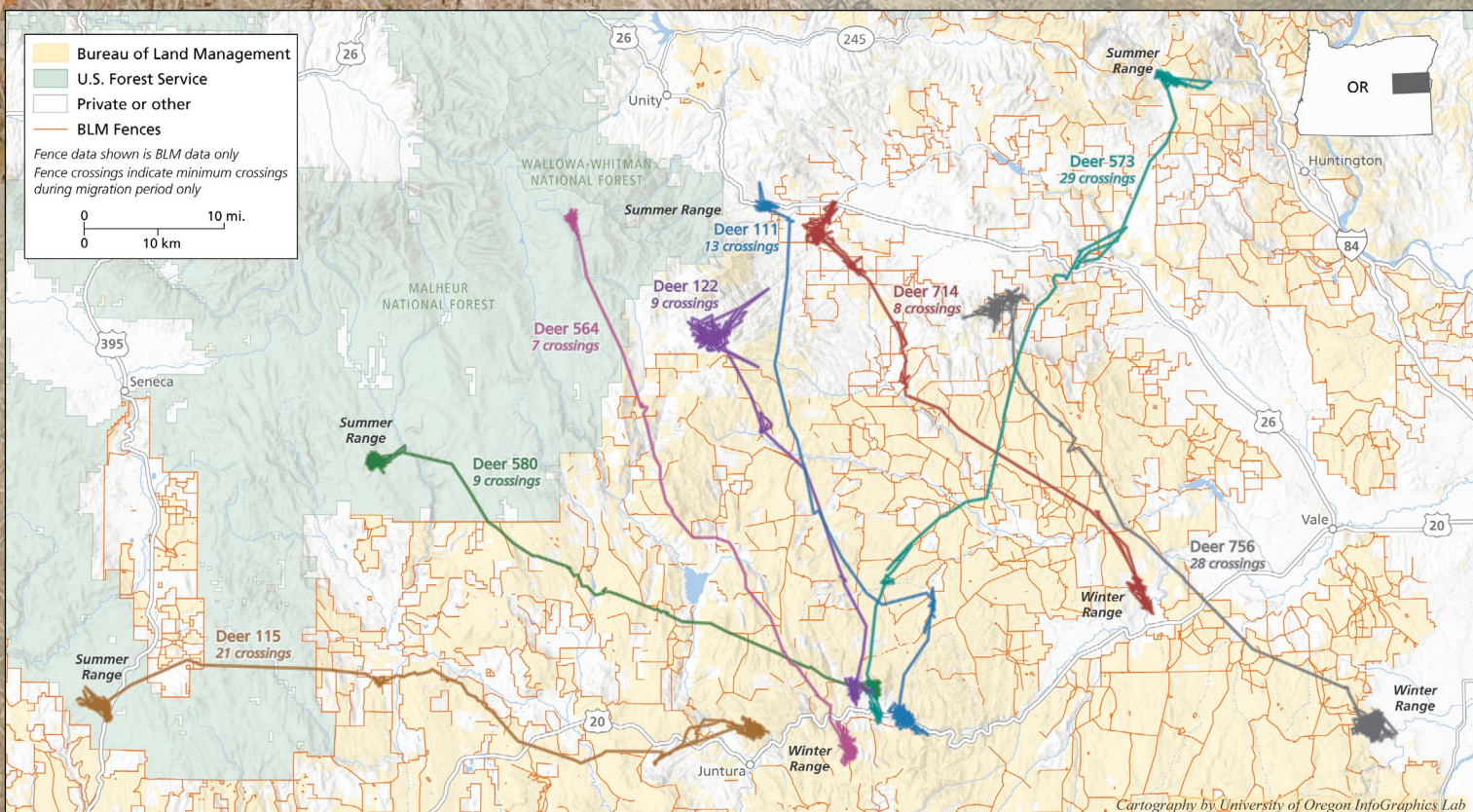


**Map 5:** Mule deer must cross many fences during migration. This dataset illustrates the minimum number of fence crossings, on BLM land alone, for these eight individuals.





Deer can become entangled in fencing when trying to jump over. Fence entanglement is a significant cause of mortality in parts of Oregon.  
Photo Credit: Tony Frates





# Conserving Migration

## MULE DEER HAVE EXPERIENCED WIDESPREAD DECLINE THROUGHOUT MUCH OF THE WEST.

In Oregon, monitoring of mule deer indicates that over the last four decades, populations have decreased by nearly 50%. Research in Oregon and other western states suggests population declines are attributable to numerous factors, including habitat loss and disturbance due to human development, <sup>19</sup> mortality caused by vehicles and fence entanglement, <sup>9, 14</sup> reduced forage availability associated with invasion of non-native grasses <sup>20</sup> and higher summer temperatures and drier conditions, <sup>21</sup> and declining nutritional quality of available forage. <sup>22</sup> Given that migration allows mule deer to access the best resources year-round, <sup>10</sup> ensuring long-term availability of migratory habitats for mule deer is imperative for mule deer conservation.

Effective conservation measures for migratory habitat may include work to reduce barriers to migration, including installation of road crossing structures and fence alterations or removal, habitat management and restoration, modifications to proposed industrial developments, conservation easements, leasing stipulations, and coordinated land-use planning for incorporating state or federal protections for migratory habitat. Importantly, these conservation measures depend on cooperation and collaboration between a diversity of stakeholders.

## Mitigating Roadways

With thousands of mule deer deaths attributable each year to collisions with vehicles and increasing traffic volumes creating barriers to mule deer movement, identifying ways to reduce or eliminate the effects of roadways on deer is paramount. In areas where collision rates are low, modification of roadside vegetation to improve driver sightlines may help reduce deer mortalities. In many locations, however, including areas where migration pathways cross highway corridors, the most effective solution is construction of wildlife crossing structures. These structures, which include large culverts, bridges, and overpasses, allow deer and other wildlife to pass under or over a roadway without having to cross traffic.

When appropriately designed and sited, these structures can greatly reduce, or in some cases even eliminate, wildlife-vehicle collisions. Oregon currently has only a handful of structures purpose-built to facilitate wildlife passage across roadways. The first structure to be completed, on U.S. Highway 97 at Lava Butte, was installed in 2012. Monitoring of this crossing in the year following construction indicated an 85% reduction in collisions with mule deer. <sup>23</sup>

While the initial costs to design and construct wildlife crossing structures are high, these structures often pay for themselves over time, as the costs associated with wildlife-vehicle collisions often exceed the expense of building a structure that allows wildlife to safely pass under or over the road. <sup>24</sup>

Nevertheless, Oregon lacks a dedicated funding source for implementing wildlife crossing projects. Grassroots efforts, community engagement, private donations, and engagement with legislators can all help to generate momentum for additional wildlife crossing efforts.

*A wildlife crossing structure on US Highway 97 at Lava Butte. These structures allow wildlife to safely pass under the highway.*

Photo Credit: Oregon Dept. of Transportation



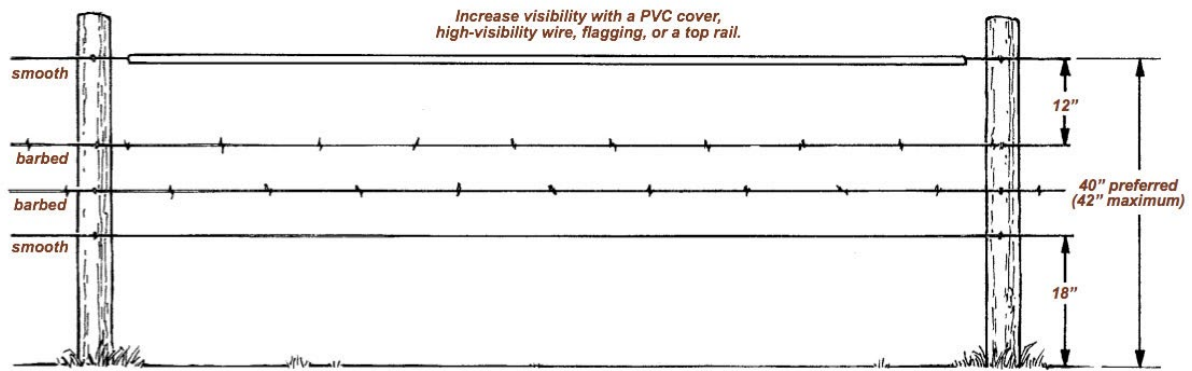


# Mitigating Fences

Fences have many beneficial uses, including containment of pets, livestock management, and protection of crops. Unfortunately, these same fences can impede or block mule deer movement, making it difficult for migrating deer to travel between their winter and summer ranges and access the high-quality food resources they need to survive and raise their fawns. Any fence will create some risk to mule deer and other wildlife, but there are some fencing designs that reduce the risk of entanglement and other negative impacts. If at all possible, fencing should be removed. If fences are necessary, they should be retrofitted or constructed to aid wildlife movement inasmuch as possible. There are many freely available guides online with information on designing fences with wildlife in mind.

For a basic wire livestock fence, the height of the top wire should be low enough for adult deer to jump, no more than 40-42 inches above the ground (**Figure 2**). The spacing between the top two strands should be at least 12 inches to lessen the risk of entanglement, and the top and bottom strands should be smooth (not barbed) to reduce the risk of injury. The bottom strand should be at least 18 inches above the ground to allow fawns to pass underneath. Woven wire should be avoided because it completely blocks the movement of mule deer fawns. Fence flags, top rails, or other markers can increase the visibility of fences for wildlife and help animals navigate crossings.

## IDEAL WILDLIFE FRIENDLY FENCE

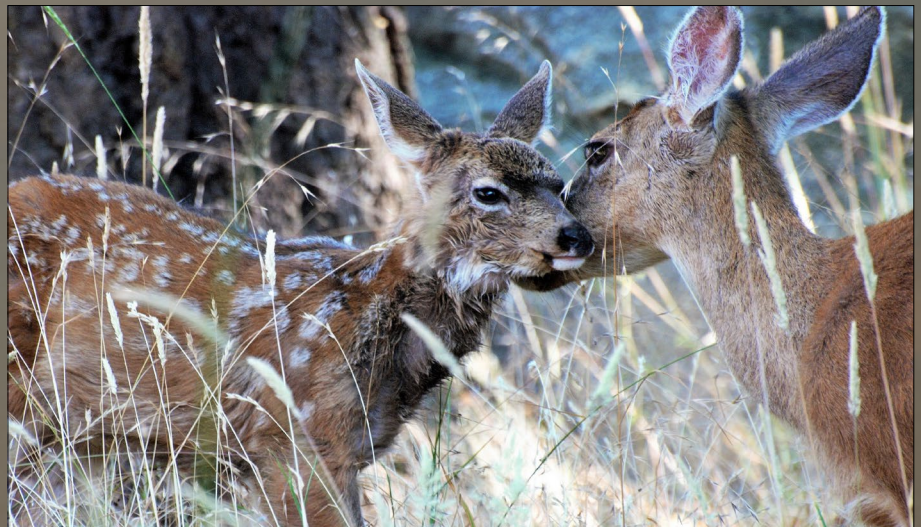


**Figure 2:** Wildlife-friendly fence design for a basic wire livestock fence.

Figure Credit: Montana Fish, Wildlife, and Parks

The friendliest fences are very visible and allow wild animals to easily jump over or slip under the wires or rails.

*Wildlife-friendly fencing designs allow mule deer fawns to safely pass underneath fences, reducing the risk of becoming separated from their mothers during migration.*

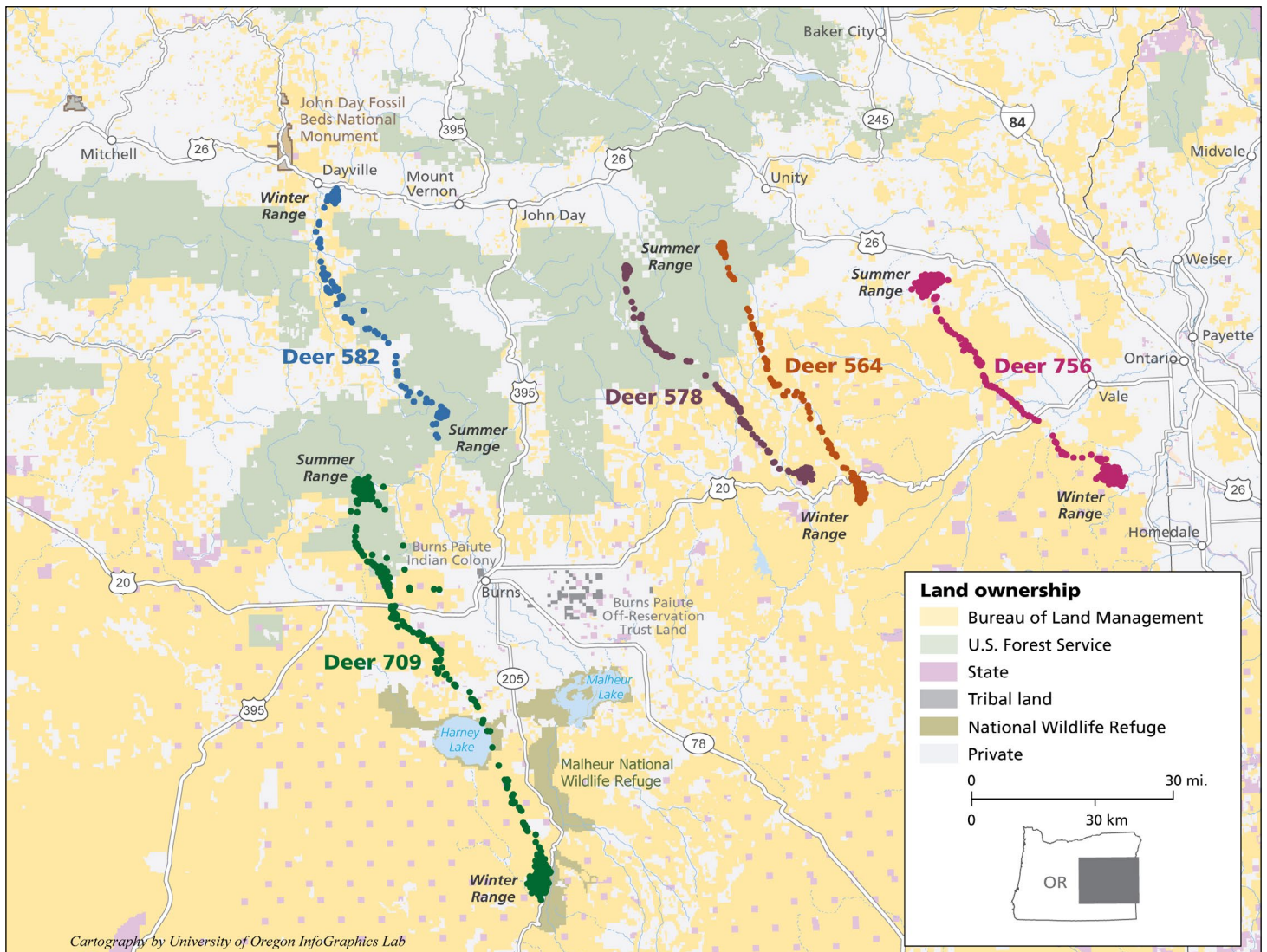




# Collaboration

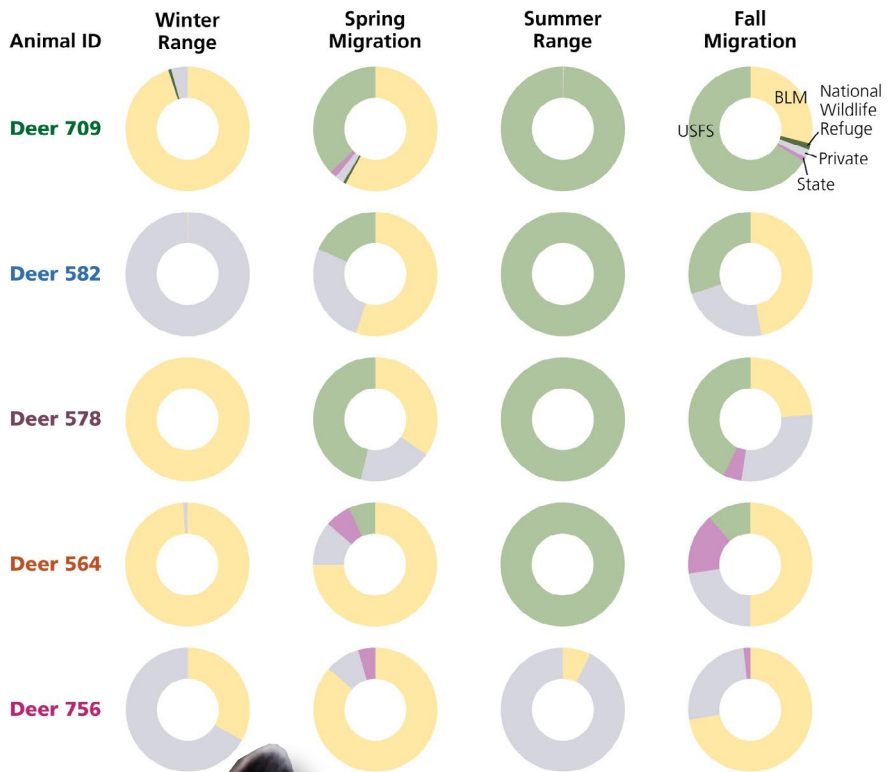
Throughout the year, mule deer use a complex patchwork of lands representing a diversity of ownerships (**Map 6**). Mule deer summer range, winter range, and migration pathways may include state, federal, tribal, and privately managed lands, in different proportions throughout different times of year (**Figure 3**). The amount of land of any given land ownership type varies both between and within herds. Some individuals may live their entire lives on public lands, spending their winters on lands managed by the BLM and summers on land managed by the Forest Service, but most individuals use, at least to some extent, privately-owned lands. The five individuals here, from the Beulah-Malheur Herd in eastern Oregon (**Map 6, Figure 3**), help illustrate the diversity of lands deer use during winter, summer, and migratory time periods.

While state and federal land managers are responsible for a great deal of land in the West, private landowners play a critical role in helping to conserve migratory habitat for mule deer. Collaboration and coordination between public and private land managers is essential. Working lands throughout Oregon help maintain the wide-open spaces needed to sustain mule deer migration. Voluntary actions for private landowners to benefit mule deer can include fencing modifications and/or removal, removal of invasive vegetation and other habitat improvements, or establishment of conservation easements. Often, financial and technical assistance is available to support private landowners engaging in these actions through the federal farm bill or state cost-share and incentive-based programs. Non-governmental organizations such as the Oregon Hunters Association, Mule Deer Foundation, Rocky Mountain Elk Foundation, and local conservation groups may provide cost-share funds to landowners to assist with habitat improvements on private lands.



**Map 6:** Migration paths of five individuals from the Beulah-Malheur herd, illustrating the diversity of land ownerships individuals cross during migration.





**Figure 3:** Proportions of time spent on different land types throughout the year. The five individuals from Map 6 (left) each use a patchwork of lands representing a mixture of public and private management.


Photo Credit: Roblyn Brown



# conclusion







**MULE DEER ARE AN ICONIC SPECIES IN THE AMERICAN WEST.** Their migratory routes, passed down from generation to generation and faithfully followed year after year, allow them to take full advantage of Oregon's dynamic environments. Sustaining these migrations in the face of human development, however, presents a challenge requiring stakeholder collaboration to implement habitat improvements and barrier mitigation efforts, as well as consideration of mule deer migration across land ownership boundaries. The difficulties outlined here are just a few of the impediments that mule deer must navigate in increasingly human-dominated landscapes. In addition to roadways and fencing, habitat conversion and disruption due to residential sprawl, resource extraction, energy development, and spread of non-native vegetation all make it difficult for mule deer to follow their migratory routes and can reduce the benefits of migration.

The more research that is completed on the remarkable journeys made by mule deer each fall and spring, the clearer it becomes that migration is critical to maintaining mule deer populations throughout the West. In Oregon, as in other western states, ensuring the long-term survival of mule deer populations means ensuring the long-term survival of mule deer migration, and a commitment to enhancing and protecting the habitats and wide-open spaces necessary for migration to continue for years to come.

Photo Credit: Jon Nelson





# Learn More



**BARRIERS**, a film produced by the Wyoming Migration Initiative with footage illustrating the barriers discussed in this brochure:  
<https://www.youtube.com/watch?v=ww5pzwbH2k>



**Oregon Conservation Strategy**  
**Key Conservation Issue:**  
<https://oregonconservationstrategy.org/key-conservation-issue/barriers-to-animal-movement/>



**Montana Fish, Wildlife, and Parks; Landowner's Guide to Wildlife Friendly Fences:**  
<https://myfwp.mt.gov/getRepositoryFile?objectID=34461>







**Colorado Parks and Wildlife; Fencing with Wildlife in Mind:**  
[https://cpw.state.co.us/Documents/LandWater/  
PrivateLandPrograms/FencingWithWildlifeInMind.pdf](https://cpw.state.co.us/Documents/LandWater/PrivateLandPrograms/FencingWithWildlifeInMind.pdf)



**Oregon Wildlife Foundation fencing manual:**  
[https://www.myowf.org/\\_files/ugd/  
aa665e\\_6e354fa16046484798688478d1cf2cde.pdf](https://www.myowf.org/_files/ugd/aa665e_6e354fa16046484798688478d1cf2cde.pdf)





# Citations

1. Sawyer, H., and M. J. Kauffman. 2011. Stopover ecology of a migratory ungulate. *Journal of Animal Ecology* 80:1078–1087.
2. Abraham, J. O., N. S. Upham, A. Damian-Serrano, and B. R. Jesmer. 2022. Evolutionary causes and consequences of ungulate migration. *Nature Ecology & Evolution* 6:998–1006.
3. Jesmer, B. R., J. A. Merkle, J. R. Goheen, E. O. Aikens, J. L. Beck, A. B. Courtemanch, M. A. Hurley, D. E. McWhirter, H. M. Miyasaki, K. L. Monteith, and M. J. Kauffman. 2018. Is ungulate migration culturally transmitted? Evidence of social learning from translocated animals. *Science* 361:1023–1025.
4. Sawyer, H., M. J. Kauffman, A. D. Middleton, T. A. Morrison, R. M. Nielson, and T. B. Wyckoff. 2013. A framework for understanding semi-permeable barrier effects on migratory ungulates. *Journal of Applied Ecology* 50:68–78.
5. Fryxell, J. M., and A. R. E. Sinclair. 1988. Causes and consequences of migration by large herbivores. *Trends in Ecology & Evolution* 3:237–241.
6. Schuyler, E. M., L. M. Ellsworth, D. M. Sanchez, and D. G. Whittaker. 2021. Forage quality and quantity in migratory and resident mule deer summer ranges. *Rangeland Ecology & Management* 79:43–52.
7. Fryxell, J. M., J. Greever, and A. R. E. Sinclair. 1988. Why are migratory ungulates so abundant? *The American Naturalist* 131:781–798.
8. Aikens, E. O., M. J. Kauffman, J. A. Merkle, S. P. H. Dwinell, G. L. Fralick, and K. L. Monteith. 2017. The greenscape shapes surfing of resource waves in a large migratory herbivore. *Ecology Letters* 20:741–750.
9. Schuyler, E. M., K. M. Dugger, and D. H. Jackson. 2019. Effects of distribution, behavior, and climate on mule deer survival. *The Journal of Wildlife Management* 83:89–99.
10. Monteith, K. L., V. C. Bleich, T. R. Stephenson, B. M. Pierce, M. M. Conner, R. W. Klaver, and R. T. Bowyer. 2011. Timing of seasonal migration in mule deer: Effects of climate, plant phenology, and life-history characteristics. *Ecosphere* 2:47.
11. Proffitt, K. M., M. Hebblewhite, W. Peters, N. Hupp, and J. Shamhart. 2016. Linking landscape-scale differences in forage to ungulate nutritional ecology. *Ecological Applications* 26:2156–2174.





12. Rolandsen, C. M., E. J. Solberg, B.-E. Sæther, B. V. Moorter, I. Herfindal, and K. Bjørneraas. 2017. On fitness and partial migration in a large herbivore – migratory moose have higher reproductive performance than residents. *Oikos* 126:547–555.
13. Huijser, M. P., J. W. Duffield, A. P. Clevenger, R. J. Ament, and P. T. McGowen. 2009. Cost–benefit analyses of mitigation measures aimed at reducing collisions with large ungulates in the United States and Canada: a decision support tool. *Ecology & Society* 14.
14. Coe, P. K., R. M. Nielson, D. H. Jackson, J. B. Cupples, N. E. Seidel, B. K. Johnson, S. C. Gregory, G. A. Bjornstrom, A. N. Larkins, and D. A. Speten. 2015. Identifying migration corridors of mule deer threatened by highway development. *Wildlife Society Bulletin* 39:256–267.
15. McInturff, A., W. Xu, C. E. Wilkinson, N. Dejid, and J. S. Brashares. 2020. Fence ecology: Frameworks for understanding the ecological effects of fences. *BioScience* 70:971–985.
16. Jakes, A. F., P. F. Jones, L. C. Paige, R. G. Seidler, and M. P. Huijser. 2018. A fence runs through it: A call for greater attention to the influence of fences on wildlife and ecosystems. *Biological Conservation* 227:310–318.
17. Xu, W., N. Dejid, V. Herrmann, H. Sawyer, and A. D. Middleton. 2021. Barrier Behavior Analysis (BaBA) reveals extensive effects of fencing on wide-ranging ungulates. *Journal of Applied Ecology* 58:690–698.
18. Harrington, J. L., and M. R. Conover. 2006. Characteristics of ungulate behavior and mortality associated with wire fences. *Wildlife Society Bulletin* 34:1295–1305.
19. Sawyer, H., M. S. Lambert, and J. A. Merkle. 2020. Migratory disturbance thresholds with mule deer and energy development. *The Journal of Wildlife Management* 84:930–937.
20. Davies, K. W., C. S. Boyd, J. L. Beck, J. D. Bates, T. J. Svejcar, and M. A. Gregg. 2011. Saving the sagebrush sea: An ecosystem conservation plan for big sagebrush plant communities. *Biological Conservation* 144:2573–2584.
21. Brown, C. L., P. K. Coe, D. A. Clark, M. J. Wisdom, M. M. Rowland, J. P. Averett, and B. K. Johnson. In press. Climate change effects on understory plant phenology: Implications for large herbivore forage availability. *Environmental Research: Ecology*.
22. Merems, J. L., L. A. Shipley, T. Levi, J. Ruprecht, D. A. Clark, M. J. Wisdom, N. J. Jackson, K. M. Stewart, and R. A. Long. 2020. Nutritional-landscape models link habitat use to condition of mule deer (*Odocoileus hemionus*). *Frontiers in Ecology & Evolution* 8.
23. Bliss-Ketchum, L. and C. Parker. 2015. Lava Butte wildlife crossing monitoring project. Portland State University, Portland, Oregon, USA.
24. Ament, R., R. Callahan, and E. Fairbank. 2018. Wildlife-vehicle conflict, crossings structures, and cost estimates. The Center for Large Landscape Conservation, Bozeman, Montana, USA..





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