**NASA DEVELOP National Program**

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Southern Rockies Ecological Forecasting II

Tracking Mule Deer for Wildlife Corridors between

Seasonal Habitats in the Southern Rockies

 **Technical Report**

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# I. Abstract

Mule deer are migratory animals that are capable of traveling as far as a few hundred miles from their summer to winter habitats. Mule deer are both economically and ecologically important to the Southern Rockies, thus their corridors need to be conserved. Declining mule deer populations caused by anthropogenic features have created a need for mapping mule deer habitats. NASA DEVELOP provided map production for the aid in the conservation of mule deer and their habitats in support of Southern Rockies Landscape Conservation Cooperative (SRLCC) and the Western Association of Fish and Wildlife Agencies (WAFWA) Mule Deer Working Group. The scope of the project was in the southern Rocky Mountains in Idaho, Wyoming, Utah, Colorado, Arizona, and New Mexico from 2011 to 2015. The objective of this project was to develop an increased understanding of why the mule deer numbers are declining by utilizing NASA Earth observation satellites. Aqua and Terra Moderate Resolution Imaging Spectroradiometer (MODIS) data were primarily used to evaluate vegetation phenology and Normalized Difference Vegetation Index (NDVI) to see how they influence migratory patterns. Terra ASTER data were utilized to create a Digital Elevation Model (DEM) to aid in determining suitable habitats. Landsat 5 TM and 8 OLI were utilized to determine current and historical land use, land cover, patch size, and winter to summer connectivity corridors. Additionally, GPS collar data was provided by the mule deer working group and the Southern Ute Indian Tribe. These factors were incorporated into a species distribution model and mule deer range maps. Finally, a methodology and tutorial for the use of the Lifemapper Species Distribution Modeler was created.

**Keywords**

Remote Sensing, GPS, Phenology, Mule Deer, Migration Patterns, Land Corridors, Habitat Loss

# II. Introduction

Mule deer (*Odocoileus heminonus*) are a migratory species that have the largest range of migration by a mammal in North America (Sawyer et al. 2014). Reports have found that mule deer are capable of traveling up to 240 km in western Wyoming, although most travel between 20-158 km (Sawyer et al. 2005/2014). Spring migration occurs as the deer follow the “green up” of grasses and forbs to primarily higher elevations; fall migration occurs when the deer follow the “brown down” and travel to lower elevations to escape harsh conditions and deep snow that occurs at higher elevations during winter months (Sawyer, 2014). As temperatures warm and plants begin to “green up” in the spring, mule deer switch from eating nutrient deficient shrubs to nutrient rich herbaceous grasses and forbs located in higher elevations (Olsen, 1992). During the summer, food is abundant and widely variant with grasses being consumed until they start to dry and cure in late summer, while forbs remain the dominant food source and consist of about 75% of their diet. The summer feeding season is in the elevation range of 1,981-3,505 m (Watkins et al. 2007). The forbs include red clover (*Trifolium pratense*), yellow sweet clover (*Melilotus officinalis*), dandelion (*Taraxacum spp*.), and huckleberry (*Vaccinium spp*.) (Olsen, 1992). In the fall, as the weather begins to cool and the first frosts begin to arrive, forbs start to wane from their diet and are replaced predominantly by shrubby vegetation; during this time forbs consist of roughly 25% of their diet (Olsen, 1992). Some especially important plants during the winter months include sagebrush (Artemisia spp.), antelope bitterbrush (*Purshia tridentate*), mountain mahogany (*Cercocarpus spp*.) and rabbit brush (*Chrysothamnus spp*.) (Olsen, 1992). Finding food becomes much more of a challenge during winter months, so their diet adjusts as their normal food supplies dwindle due to “brown down” (Monteith et al. 2011). During this time, their diets consist mainly of trees and shrubs (Olsen, 1992). Supreme wintertime habitats consist of approximately 45% shrubland, 45% coniferous forest, and 10% forbs and grasslands (Olsen, 1992) and are generally below 2,286 m in elevation (Watkins et al. 2007).

Habitat fragmentation, primarily caused by anthropogenic disturbances, is affecting the migratory patterns of mule deer. Habitat fragmentation is caused by the different levels of property ownership of federal, state, and privately owned lands. Federal lands occupy approximately 640 million acres, make up 28% of the total land in the United States, and are divided between disconnected private, state, and federal grounds (Gorte et al. 2012). The creation of oil and gas lines, along with urban sprawl, have caused indispensable migratory corridors to disappear, which in turn is causing a decline in mule deer populations (Lendrum et al. 2013). In Wyoming alone there has been a 36% decrease in mule deer population from 1991-2012 (Madison, 2014). Herds near more-developed areas are migrating earlier and moving faster to avoid anthropogenic features to get to lower elevations in time for the cold season (Sawyer et al. 2014). These changes in migration patterns have resulted in human-caused accidents and death (Lendrum et al. 2013). Mule deer need land corridors between these different land classes because, as migratory animals, they move seasonally between high and low elevations (Sibbald and Gordon, 2001). These migratory paths have been tracked with GPS technology that is accurate to 30 m to the locations of the collared mule deer (Tomkiewics et al. 2010). The tagging process is referred to biologging and relays data about animal’s movements, behavior, and their environment (Rutz and Hays, 2009).

Southern Rockies Ecological Forecasting team II (SREF) has produced maps that show the best summer highlands, winter habitats, and the migration routes. These maps will help Western Association of Fish and Wildlife Agencies (WAFWA) Mule Deer Working Group and Southern Rockies Landscape Conservation Cooperative (SRLCC) create and preserve migration corridors. The study period spans 4 years, from 2011 to 2014, and looks at the mule deer population located within the borders of the SRLCC. Located in the Southern Rocky Mountains, the SRLCC spans 6 states including Arizona, Colorado, Idaho, New Mexico, Utah and Wyoming, and encompasses about 516,754 km2. NASA DEVELOP National Program and SREF has partnered with WAFWA as well as the SRLCC to examine ways in which humans can conserve land for mule deer and the decline in mule deer’s population.

# III. Methodology

Data Acquisition

1. Land Cover

The USGS 2011 National Landcover Database (NLCD), which has a spatial resolution of 30 m is based predominantly on a decision-tree classification of 2011 Landsat satellite data, was downloaded from the Multi-Resolution Land Characteristics Consortium (MRLC).

1. Southern Rockies LCC Boundary

The shapefile of the SRLCC boundary was downloaded through USGS’s ScienceBase catalog. The SRLCC spans 6 states and covers about 516,754 km2.

1. Mule Deer Habitat Ranges

Mule deer habitat range data was downloaded from Utah State University’s Remote Sensing and Geographic Information Systems Laboratory website. The database included 6 different shapefiles for the mule deer’s limited range, year-round population, summer range, winter range, winter concentration, and other important habitat. The 6 habitat areas were mapped using a minimum mapping unit of roughly 6 mi2 and demarcated onto 1:250,000 scale sheet maps. The mule deer habitat range data was later used as a comparison to our mule deer range maps.

1. Elevation

Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) on board Terra utilizes a backwards looking telescope to create stereo coverage to obtain elevation data. ASTER Digital Elevation Model (DEM) data products are produced with a 30 m resolution. The Global Digital Elevation Model V002 was downloaded from SGS global data explorer (GDEX) website and incorporated into our final Mule Deer Range Map.

1. Climate Data

Parameter-elevation Relationships on Independent Slopes Model (PRISM) Climate Group is modeled using climatologically-aided interpolation (CAI). PRISM datasets that included precipitation data in mm and mean temperature data were obtained. New M3 and D2 versions of AN81m, with a 4 km resolution, and AN81d improved consistency of the data. The data were downloaded in monthly intervals between January 2011 and December 2015. The DEM was used for the predictor grid.

1. Vegetation Phenology Data

Land Surface Phenology (LSP) and vegetation phenology products were obtained through the Utah State Forest Service (USFS) ForWarn System for the years 2011, 2012, 2013, and 2014 at a 232 m resolution. The ForWarn System relies on MODIS satellite data that tracks changes in the NDVI and shows average, minimum, and maximum Normalized Difference Vegetation Index (NDVI) values.

Data Processing

1. Land Cover
   1. Land Cover

The NLCD was clipped to the SRLCC boundary layer and incorporated into the mule deer range maps.

* 1. Mule Deer Habitat Ranges

The seasonal ranges were extracted from the dataset and created as a layer.

* 1. SRLCC Boundary

The shapefile of the SRLCC boundary was added to the used as the extent of the mule deer range maps.

1. DEM and Climate
   1. DEM

One raster file was produced to include and mosaic all of the ASTER data. The file was then clipped to show the study area and the mule deer winter range. Statistics that included mean elevation for the winter range were then calculated into ArcMap.

* 1. PRISM

PRISM monthly datasets were converted from Band Interleaved by Line (BIL) image files to .tiff files. Python was then used to clip the study area and average monthly data to yearly data.

1. Vegetation phenology
   1. An Iterative Self-Organizing Data Analysis Technique (ISODATA) unsupervised classification technique in ERDAS Imagine was used to stack MODIS based NDVI and day of year phenology products into a single image and then classify it into 30 distinct classes.

Data Analysis

We created MODIS day of year phenology, MODIS NDVI vegetation phenology, and MODIS vegetation phenology with a DEM, slope and aspect layers. The dataset were all added into their own respective maps and cluster busted. Cluster busting is a technique of running an unsupervised classification then masking your conclusive results to run an unsupervised classification again on the inconclusive results. All of the maps with cluster busted ISODATA results were then divided into 30 classes. ISODATA 30 distinct classes were divided into six main classes with multiple subclasses. The six main classes that were included in the maps were mule deer’s limited range, year-round population, summer range, winter range, winter concentration, and other important habitat with subclasses for certain layers due to the fact that some layers encompassed multiple Utah State classes. This technique allowed us to compare our results to the Utah State University mule deer habitat map.

# IV. Results & Discussion

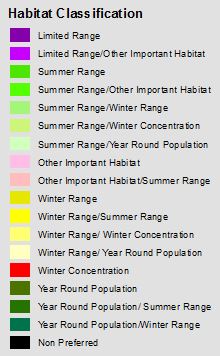
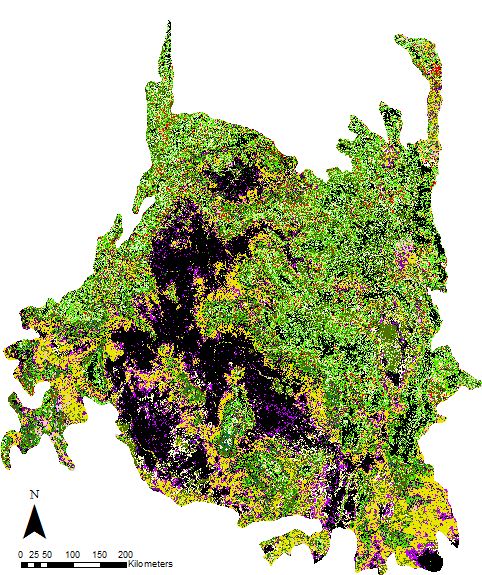


Figure 1: 2012 Vegetation phenology data results map using the cluster busting technique.

Initially, data for the years 2011 to 2015 were to be used while looking at mule deer migration patterns and to search for potential corridors. However, we were unable to obtain 2015 PRISM climate data, so we acquired PRISM data for the years 2011 and 2014 to begin creating maps using ISODATA and K Means. Time constraints and subjectivity from already completed maps, along with software problems using K Means required us to change paths and begin using a cluster busting technique. The time constraints allowed us to look at and create cluster busting maps for the years 2012 and 2014. We cluster busted MODIS day of year phenology and MODIS NDVI vegetation phenology. We were then able to compare our maps to the Utah State’s mule deer habitat map. Our maps, though similar, were not exact matches to Utah State’s map. One problem that occurred to make this maps different was the small winter range and winter concentration classes. The SRLCC has a large boundary that contains many different types of vegetation. Utah State, on the other hand, has a much smaller boundary so there were not as many extreme differences in vegetation. After creating our final maps we were unable to create an accuracy assessment, such as an assessment using GPS collar data, because of our time constraints.

Future work could include using cluster busting techniques for the years 2011 through 2015. The use and cluster busting of snow depth and duration data, as well as PRISM climate data would be beneficial to research for mule deer conservation. Obtaining GPS collar data that tracks mule deer migration would be useful for accuracy assessments.

# V. Conclusions

Mule deer are a keystone species known to South West United States and their population is in decline. The establishment of land corridors is crucial to help the population maintain a healthy population size.  NASA Earth Observing System was used to identify current mule deer habitats and ranges. The initial outcome of this project was to determine mule deer habitats and establish potential corridors. The final outcome included a MODIS day of year phenology and a MODIS NDVI vegetation phenology map, with a tutorial on the process of cluster busting. A tutorial will help the method of cluster busting for future projects and give our partners, SRLCC and WAFWA, the ability to replicate this project for the preservation of mule deer habitat.

# VI. Acknowledgments

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# VII. References

Gorte, R. W., Vincent, C. H., Hanson, L. A., & Rosenblum, M. R. (2012). Federal Land

Ownership: Overview and Data (pp. 1-27) (United States of America, Congressional Research Service, Congress).

Lendrum, P. E., Anderson, C. R., Monteith, K. L., Jenks, J. A., & Bowyer, R. T. (2013). Migrating Mule Deer: Effects of Anthropogenically Altered Landscapes. Public Library of Science ONE, 8(5).

Madison, C. (2014). Icon of the American West. National Wildlife (World Edition), 53(1).

Monteith, K. L., Bleich, V. C., Stephenson, T. R., Pierce, B. M., Conner, M. M., Klaver, R. W., & Bowyer, R. T. (2011). Timing of seasonal migration in mule deer: Effects of climate, plant phenology, and life-history characteristics. Ecosphere, 2(4).

Olson, R. (1992). Mule deer habitat requirements and management in Wyoming. Department of Renewable Resources: University of Wyoming. Retrieved from: http://www.wyomingextension.org/agpubs/pubs/B965R.pdf. Accessed: February 5, 2015.

Rutź, C., & Hays, G. C. (2009). New frontiers in biologging science. Biology Letters, 5(3), 289-292.

Sawyer, H., Hayes, M., Rudd, B., & Kauffman, M. (2014). The Red Desert to Hoback Mule Deer Migration Assessment. Retrieved February 08, 2016, from http://migrationinitiative.org/sites/migration.wygisc.org/themes/responsive\_blog/ images/RDH\_Migration\_Assessment\_Final.pdf

Sawyer, H., Lindzey, F., & McWhirter, D. (2005). Mule deer and pronghorn migration in western Wyoming. Retrieved February 10, 2016, from http://www.bioone.org/doi/full/10.2193/00917648%282005%2933%5B1266%3AMD APMI%5D2.0.CO%3B2

Sibbald, A., & Gordon, I. J. (2001). Tracking animals with GPS: An international conference held at the Macaulay Land Use Research Institute, Aberdeen, 12-13 March 2001. Aberdeen: Macaulay Institute.

Tomkiewicz, S. M., Fuller, M. R., Kie, J. G., & Bates, K. K. (2010). Global positioning system and associated technologies in animal behaviour and ecological research. Philosophical Transactions of the Royal Society B: Biological Sciences, 365(1550), 2163-2176.

Watkins, B. E., C. J. Bishop, E. J. Bergman, A. Bronson, B. Hale, B. F. Wakeling, L. H. Carpenter, and D. W. Lutz. 2007. Habitat Guidelines for Mule Deer: Colorado Plateau Shrubland and Forest Ecoregion. Mule Deer Working Group, Western Association of Fish and Wildlife Agencies.

# VIII. Content Innovation

# IV. Appendices