**NASA DEVELOP National Program**

NASA Langley Research Center

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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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Tyler M. Rhodes (Project Lead)

Mike Sclater

Amanda Flake

Allison Chappell

Maggie Jenkins

Cody Walker

Dr. Kenton Ross,NASA DEVELOP National Program (Science Advisor)

Previous Contributors:

Ross Reahard

Teresa Feen

Jeri Wisman

# I. Abstract

[Placeholder - do not put anything here until the final draft submission. The abstract in the project summary is where the working draft of the abstract should “live”]

**Keywords**

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

# II. Introduction

Mule deer, *Odocoileus heminonus*, are considered a migratory species with reports that have mule deer traveling up to 241 km in western Wyoming (Sawyer et al. 2014), although average migrations distances were around 20-158 km (Sawyer et al. 2005). Migration occurs in the spring and fall months. Spring migration occurs as the deer follow the “green up” of grasses and forbs to primarily higher elevations and fall migration occurs when the deer travel to lower elevations to escape harsh conditions and deep snow that occurs at higher elevations during winter months (Sawyer 2014). Finding food becomes comparatively challenging during winter months, so their diet adjusts as their normal food supplies dwindle due to vegetative “brown down” (Monteith et al. 2011). During this time, their diets consist mainly of trees and shrubs (Olsen 1992). 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 6,500-11,500 feet (Watkins et al. 2007). The forbs include red clover (*Trifolium pratense*), yellow sweet clover (*Melilotus officinalis*), dandelion (*Taraxacum*), 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 (*Prushia tridentate*), mountain mahogany (*Cercocarpus spp.*) and rabbit brush (*Chryosthanmus spp.*) (Olsen 1992). Supreme wintertime habitats consist of approximately 45% shrubland, 45% coniferous forest, and 10% forbs and grasslands (Olsen 1992) and are generally below 7,500 feet in elevation (Watkins et al. 2007).

Habitat fragmentation, primarily caused by anthropogenic disturbances, is affecting the migratory patterns of mule deer. 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 (Lendrum et al. 2013). Daryl Lutz of the Wyoming Game and Fish Department noted that, in Wyoming alone, there has been a 36% decrease in mule deer population from 1991-2012 (Madison 2014). Some herds of mule deer do not necessarily avoid roads and other anthropogenic features but the increase in human features caused these herds to migrate at different times. Research shows that herds near more-developed areas are migrating earlier and moving faster. The reason for this is so they can get around these areas and to lower elevations in time for the cold season. These changes in migration patterns have also caused more deaths of mule deer as more get killed via car accidents, getting stuck in fenced in areas, and other human-induced accidents (Lendrum et al. 2013). Habitat fragmentation is caused by the different levels of property ownership of federal, state, and privately owned lands. Federal lands, occupying 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). Mule deer need land corridors between these different classified lands because as migratory animals, they move seasonally between high-elevation summer ranges with abundant food and low-elevation winter ranges with nutrient deficient shrubs (Sibbald and Gordon, 2001). These migratory paths have been tracked with collared mule deer and GPS technology that is accurate to 30m locations (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 (SREF) team II has produced maps that show the best summer highlands and winter habitats and the long migration routes in between them for the deer that will help the project partners, Western Association of Fish and Wildlife Agencies (WAFWA) Mule Deer Working Group and Southern Rockies Landscape Conservation Cooperative (SRLCC), create corridors. The study period spans four years, from 2011 to 2015, and looks at the mule deer population located within the borders of the SRLCC located in the southern Rocky Mountains that spans six states including Arizona, Colorado, Idaho, New Mexico, Utah, and Wyoming encompassing about 516,754 square km. The objective is to examine ways in which humans can conserve land for mule deer and mitigate the decline in mule deer populations.

# III. Methodology

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Data Acquisition

1. Land Cover

The United State Geological Survey (USGS) 2011 National Landcover Database (NLCD), which has a spatial resolution of 30 meters, is based predominantly on a decision-tree classification of 2011 Landsat satellite data and 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 six states and covers about 516,754 square km.

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 six different shapefiles for the mule deer’s limited range, year-round population, summer range, winter range, winter concentration, and other important habitat. The six habitat areas were mapped using a minimum mapping unit of roughly six square miles 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) is one of the five instrument sensor systems on board Terra which utilizes a backwards looking telescope to create stereo coverage to obtain elevation data. ASTER Digital Elevation Model (DEM) data products are produced with a 30m resolution. The Global DEM V002 was downloaded from USGS 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 to the data. The data were downloaded in monthly intervals between January 2011 and December 2015. A 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 2011-2014 at a 232 m resolution. The ForWarn System relies on Moderate Resolution Imaging Spectroradiometer (MODIS) satellite data that tracks changes in the Normalized Difference Vegetation Index (NDVI) and shows average, minimum, and maximum 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. It was then classified into 30 distinct classes such as….

Data Analysis

Data were analyzed using ArcMap 10.3.1 and ERDAS Imagine software.

# IV. Results & Discussion

Insert images, graphs, maps, charts, etc. here. Choose the most important results to highlight here. No word cap, but two to six pages is a good range.

Things to discuss:

* Analysis of Results: What can you tell from your graphs, images, etc? What does this mean for your project?
* Errors & Uncertainty: What factors could you not account for, what things didn’t work out like you expected they would, etc.
* Future Work: If this project was to be selected for another term, what would be the focus? What other areas would be of interest?

# V. Conclusions

Final conclusions. Word count: 200-600 (~a page).

# VI. Acknowledgments

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Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration.

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# IV. Appendices

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