**NASA DEVELOP National Program**

**2018 Fall Project Proposal**

**California – JPL**

**Mojave Desert Ecological Forecasting**

*Monitoring Bighorn Sheep Habitat by Assessing Vegetation, Precipitation, and Soil Characteristics*

**Project Overview**

***Project Synopsis*:** The National Park Service, California Department of Fish and Wildlife, Oregon State University, and Sierra Nevada Bighorn Sheep Foundation previously partnered with NASA DEVELOP in identifying trends in precipitation and vegetation related to bighorn sheep (BHS) (*Ovis canadensis*) presence and habitat selection in the Mojave Desert. The second term of this project will further utilize Aqua and Terra MODIS, SMAP, SRTM, Landsat TM and OLI, and Sentinel-2 MSI data to evaluate those spatio-temporal vegetation characteristics. Using data collected from 2005-2018, the team will investigate vegetation and soil types, and elevation to determine correlations in bighorn sheep resource selection that will benefit the partners’ habitat modeling efforts. Normalized Difference Vegetation Index and precipitation products from the previous term will be used to aid in habitat selection analysis and modeling. Project partners will use project end products to make management and monitoring decisions regarding habitat and water availability, especially during drought conditions.

***Community Concern:*** Big Horn Sheep populations and habitat in California are affected by drought and changing ecologic conditions, including shrinking habitat resource availability, poor resource quality, and increased mortality due to predation and disease. Mojave BHS populations have limited migration range and difficulty adapting to new environments. The BHS play a key ecological role in the Mojave Desert, but are currently fragmented into small and isolated herds due to limited habitat resource and food availability. As such, it is difficult to monitor, assess, and manage BHS populations with respect to water availability and vegetation conditions. The BHS are selective feeders, preferentially choosing the most nutritious forage, so to aid effective widespread planning and management decisions, a synoptic, holistic view of resource availability across the region is needed.

***Source of Project Idea:*** This project originated during conversations between NASA DEVELOP’s National Program Office personnel and staff from the National Park Service Mojave Inventory & Monitoring Network. The project has expanded to include a larger regional, multi-organizational BHS research group.

***National Application Areas Addressed:*** Ecological Forecasting

***Study Location:*** Mojave Desert, CA

***Study Period:*** January 2005 – June 2018; Forecasting to 2025

***Advisors:*** Dr. Kenton Ross (NASA Langley Research Center), Natasha Stavros (NASA Jet Propulsion Laboratory, California Institute of Technology), Joseph Spruce (Science Systems & Applications, Inc.)

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **National Park Service, Mojave National Preserve** | Debra Hughson, Chief of Science and Resource Stewardship | End User | No |
| **National Park Service, Biological Resources Division, Wildlife Health Branch** | Nathan Galloway, Disease Ecologist; Jenny Powers, Wildlife Veterinarian | End User | No |
| **California Department of Fish and Wildlife, Wildlife Branch, Game Management** | Regina Abella, Desert Bighorn Sheep Program Coordinator;  Dave German, Research Analyst;  Paige Prentice, Desert Bighorn Sheep Biologist;  Jeff Villepique, Wildlife Biologist | End User | No |
| **Oregon State University, Department of Fisheries and Wildlife** | Daniella Dekelaita, PhD student; Clinton Epps, Associate Professor | Collaborator | No |
| **Sierra Nevada Bighorn Sheep Foundation** | John Wehausen, Bighorn Sheep Biologist | Collaborator | No |

***End-User Overview***

***End User’s Current Decision-Making Process:***The California Department of Fish and Wildlife partners in the Mojave Desert region currently monitor BHS populations to assess impacts of disease and anthropogenic disturbances using collared GPS devices. They also use GPS collars to track where sheep are foraging and monitor habitat selection. Based on their observations, the end users are responsible for allocating resources towards BHS management and determining locations that need additional habitat conservation measures. The partners use remote sensing in addition to *in situ* monitoring to assess sheep habitat and resource availability.

***End User’s Capacity to Use NASA Earth Observations:***

*National Park Service, Mojave National Preserve* – The National Park Service (NPS) staff at the Mojave National Preserve have used Terra/MODIS Gross Primary Productivity products (MOD17A2 8-day composite at 1 kilometer spatial resolution) to estimate forage production for a cattle grazing allotment to guide management decisions. This NASA DEVELOP project will build upon partner research and the last term’s end products by providing MODIS NDVI data at a higher 250 meter spatial resolution on vegetation canopy greenness phenology.

*National Park Service, Biological Resources Division, Wildlife Health Branch* – The Wildlife Health Branch is familiar with NASA Earth observations and currently uses studies based on NASA data that are attempting to identify relationships between BHS and their ecosystems.

*California Department of Fish and Wildlife, Wildlife Branch, Game Management* – The Department has used NASA Earth observation data (Landsat, MODIS) to quantify snow cover, incorporate vegetation indices into montane BHS resource selection models, and to quantify plant species distribution.

***Collaborator & Boundary Organization Overview***

***Collaborator Support:***

*Oregon State University, Department of Fisheries and Wildlife* – Oregon State University is examining how BHS survival, reproduction, and movement are influenced by spatial and temporal environmental variation and respiratory disease. Location point data will be used by Daniella Dekelaita to examine BHS movement and resource use within the Mojave National Preserve and nearby areas, and is potentially available for project use.

*Sierra Nevada Bighorn Sheep Foundation* – The Sierra Nevada Bighorn Sheep Foundation will contribute subject-matter expertise about BHS and the Mojave Desert ecosystem in addition to ground-truth data to help validate and assess remotely-sensed observations.

***Project Communication & Transition Overview***

***In-Term Communication Plan*:** The Center Lead will initiate the first partner meeting, but the Project Lead will be the main POC for the project throughout the term. Biweekly telephone calls will be used to discuss progress and receive feedback from partners. Email exchanges will occur as needed during the term.

***Transition Plan*:** A handoff at the end of the term will be conducted virtually via WebEx for the partners who cannot attend the official JPL close-out event. The team will present their findings and accompanying tutorial so partners can replicate the project work at their own convenience. Software release is not anticipated.

**Earth Observations Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 5 TM** | Surface reflectance, spectral vegetation indices | Landsat 5 TM will be used to derive vegetation classes and assess long-term trends in vegetation availability and health. |
| **Landsat 8 OLI** | Surface reflectance, spectral vegetation indices | Landsat 8 OLI will be used to derive vegetation classes and assess long-term trends in vegetation availability and health. |
| **Terra MODIS** | Surface reflectance, spectral vegetation indices | Terra MODIS will be used to derive vegetation classes to assess long-term trends in availability and health. |
| **Aqua MODIS** | Surface reflectance, spectral vegetation indices | Aqua MODIS will be used to derive vegetation classes and assess long-term trends in vegetation availability and health. |
| **Sentinel-2 MSI** | Surface reflectance | Sentinel-2 MSI will be used to identify current vegetation distributions as a comparison to Landsat- and MODIS-based results. |
| **SRTM** | Digital Elevation Model | SRTM will provide elevation values throughout the study area. |
| **SMAP** | Soil moisture | SMAP will be used to assess interactions between soil moisture and vegetation indices. |

***Ancillary Datasets:***

California Department of Fish and Wildlife BHS point locations – Locations of BHS from GPS collars will be used to generate resource selection functions

Oregon State University identified Bighorn Sheep ranges – Previously identified locations of Bighorn Sheep habitat will be used for comparisons to satellite-derived habitat ranges

USGS National Land Cover Database (NLCD) – Will be used to assess general land cover types

LANDFIRE Database existing vegetation type – Will be used to assess more specific vegetation types of interest

USGS National Gap Analysis Program (GAP) – Will be used to determine land cover types of interest

***Modeling:***

USGS Software for Assisted Habitat Modeling (SAHM) – (POC: Colin Talbert, USGS Fort Collins Science Center)

***Software & Scripting:***

Esri ArcGIS – map creation

Exelis ENVI – raster manipulation and analysis, image enhancement, image classification

ESA Sentinel Application Platform (SNAP) – preprocessing Sentinel-2 raster imagery

**Decision Support Tool & End Product Overview**

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Partner Use** | **Datasets & Analyses** | **Software Release Category** |
| **Forage vs. Non-Forage Vegetation Map** | Partners will use these maps to determine priority BHS forage areas for monitoring and management. | Combined outputs from Landsat 5 TM, Landsat 8 OLI, Terra MODIS, Aqua MODIS, and Sentinel-2 MSI will be used to classify areas as forage and non-forage. | I |
| **Spatial Correlation Map of Environmental Factors Related to Big Horn Sheep Habitat Use** | Partners will use these maps to look at relationships between environmental variables (vegetation health, elevation, and soil moisture) of interest and BHS distribution. Partners will also be able to apply the individual raster layers for future modeling. | Landsat 5 TM, Landsat 8 OLI, Terra MODIS, Aqua MODIS, Sentinel-2 MSI, SRTM, and SMAP will be used to create raster layers of vegetation types, elevation, and soil moisture respectively. | I |
| **Big Horn Sheep Predicted Habitat Map** | This preliminary map will assist partners to understand potential BHS distribution by the year 2025 and will aid in managing forage sites. | Predicted distribution of BHS habitat will be based on correlations between diverse input layers, including SMAP soil moisture, and Terra/Aqua MODIS vegetation, *in situ* BHS GPS locations, Landsat vegetation, Sentinel-1 vegetation, and NDVI and precipitation from the first term. Raster layers from the above end product will be used as inputs in the USGS SAHM model. | N/A |
| **Habitat Assessment Tutorial and Guide** | Partners will use a write-up of project methodology to continue using NASA Earth observations to inform management decisions. | An instruction manual detailing steps taken to use the SAHM model and replicating input rasters. | N/A |

***End-User Benefit*:** End products produced by both terms will support management of BHS and their habitat by providing additional datasets to inform resource availability, disease mitigation, and maintaining habitat connectivity in the Mojave Desert region. This project will complement the previous term and other studies on nutrient availability and population dynamics conducted by collaborating organizations, enabling better resource planning and efficiency and an improved understanding of the BHS habitat vegetation and precipitation dynamics of the region.

**Project Timeline & Previous Related Work**

***Project Timeline:*** 2 Terms: 2018 Spring to 2018 Fall

***Multi-Term Objectives:***

* **Term 1:** 2018 Spring (Virginia – Wise) – Mojave Desert Water Resources
  + Term one focused on creating a time-series of vegetation and precipitation indices and assessing relationships between the two parameters. Initial analyses focused on identifying trends in precipitation that typically preceded corresponding increases in vegetation greenness. It also researched use of the SWAT model while using the SAHM to predict vegetation indices. The project team also assessed these time-series datasets with *in situ* data available from project partners.
* **Term 2 (Proposed Term):** 2018 Fall (California – JPL) – Mojave Desert Ecological Forecasting
  + The second term of this project will focus on creating more detailed vegetation type classification products (forage vs. non-forage). Project partners have also requested additional layers for study, such as vegetation type and soil moisture (in addition to vegetation indices and precipitation from last term), in order to determine patterns in BHS movement. These layers could also be incorporated into the USGS SAHM model to predict BHS habitat. The California – JPL closeout will provide an opportunity to hand-off the project results to partners and demonstrate the tutorials in person.

***Previous Terms:***

2018 Spring (VA) – Mojave Desert Water Resources: Assessing Vegetation and Precipitation Indices to Aid Bighorn Sheep Habitat Monitoring and Management

***Related DEVELOP Work:***

2016 Summer (CO) – Laramie Mountains Ecological Forecasting: Modeling Aspen Distribution Utilizing NASA Earth Observations to Identify Critical Habitat for Mule Deer and Elk in the Laramie Range, Wyoming

2016 Spring (LaRC) – Southern Rockies Ecological Forecasting: Tracking Mule Deer for Wildlife Corridors between Seasonal Habitats in the Southern Rockies

**Notes & References:**

***Notes*:**

California Department of Fish and Wildlife have artificial drinker systems featuring rain gauges that transmit via satellite. They may also be able to contribute some personnel time if further on-the-ground validation is needed.

Habitat utilization is also affected by topography (e.g. slope, insolation, and ruggedness) and must be taken into account in resource selection models.

* Human-supplied water is a management alternative. Investigating how spatio-temporal variations in forage quality and quantity relate to resource selection could yield valuable insights into predicting where provisional water might achieve the greatest benefit.

***References:***

Creech, T. G., Epps, C. W., Monello, R. J., & Wehausen, J. D. (2016). Predicting diet quality and genetic diversity of a desert-adapted ungulate with NDVI. *Journal of Arid Environments*, *127*, 160-170. https://doi.org/10.1016/j.jaridenv.2015.11.011

Epps, C. W., Mccullough, D. R., Wehausen, J. D., Bleich, V. C. & Rechel, J. L. (2004). Effects of climate change on population persistence of desert-dwelling mountain sheep in California. *Conservation Biology*, *18*(1), 102–113. https://doi.org/10.1111/j.1523-1739.2004.00023.x

Funk, C., P. Peterson, M. Landsfeld, D. Pedreros, J. Verdin, S. Shukla,… Michaelsen, J. (2015). The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes. *Scientific Data*, 2, 150066. doi:10.1038/sdata.2015.66

Wehausen, J. D. (1995). Fecal measures of diet quality in wild and domestic ruminants. *Journal of Wildlife Management*, *59*(4), 816-823. doi: 10.2981/10-111

Wehausen, J. D. (2005). Nutrient predictability, birthing seasons, and lamb recruitment for desert bighorn sheep. *In J. Goerrissen and J. M. Andre (Eds.), Symposium Proceedings for the Sweeney Granite Mountains Desert Research Center 1978-2003: Quarter Century of Research and Teaching*, 37-50. doi: 10.1111/j.1365-294X.2006.03103.x