**Yellowstone Ecological Forecasting II**

*Assessing Change in Aspen Extent in Northern Yellowstone National Park*

**Project Team**

***Project Team:***

Vanessa Bailey (Project Lead)

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***Advisors & Mentors:***

Dr. Marguerite Madden (University of Georgia, Center for Geospatial Research)

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**Project Overview**

***Project Synopsis:***

Wolf removal and reintroduction in Yellowstone National Park have had profound effects on the ecosystem, especially on the interactions of wolves, elk, and aspen. In partnership with the National Park Service, Utah State University, and the University of Wisconsin–Stevens Point, the team analyzed aspen extent in 1954 by digitizing historical imagery and quantified 2021 aspen extent using a random forest model and a phenological method. This project quantified and visualized 70 years of change in aspen extent in northern Yellowstone National Park using NASA Earth observations and aerial imagery, which can be used to inform future rewilding decisions.

***Abstract:***

Aspen stands in Yellowstone National Park have been indirectly affected by the removal and reintroduction of wolves in 1926 and 1995, respectively. The National Park Service has a strong interest in the trophic cascade of wolves, elk, and aspen due to their ecological importance. In partnership with Yellowstone National Park, Utah State University, and the University of Wisconsin–Stevens Point, this project analyzed data from 1954 and 2021 to determine change in aspen extent at a landscape scale. The team used historical aerial imagery to determine aspen stand extent in 1954 with particular focus on 113 belt transects provided by the team’s partners. To determine aspen stand extent in 2021, the team processed Landsat 8 Operational Land Imager (OLI) and Sentinel-2 Multispectral Instrument (MSI) imagery using a random forest classification. The team then refined outputs with a phenological approach to distinguish between deciduous and evergreen vegetation. The team produced maps of aspen extent for 1954 and 2021. Despite limitations in scales of comparison, the results generally indicate a decline in aspen stand extent over time. This project provides greater context for monitoring aspen stands, understanding the landscape-scale impacts of wolf reintroduction, and communicating the trophic cascade story to the public.

***Key Terms:***

*Populus tremuloides*, trophic cascade, random forest, phenology, aerial imagery, digitization, wolves

***National Application Area Addressed:*** Ecological Forecasting

***Study Location:*** Yellowstone National Park, WY and MT

***Study Period:*** September 1954 to October 2021

***Community Concerns:***

* As one of the few deciduous trees in the region, aspen holds significant value for biodiversity, ecosystem health, wilderness character, and tourism at Yellowstone National Park. Monitoring the health and recovery of these trees is important for the ecological success of the area.
* Over the past few decades, increased elk browsing on saplings has potentially altered the age class structure of aspen stands. Aspen stands with little diversity in age class and a higher proportion of mature trees are more vulnerable to die-off from biotic and abiotic stressors. Decline in aspen could result in negative outcomes for other species, including understory plants, migratory birds, and riparian wildlife.
* Following wolf reintroduction to Yellowstone in the 1990s, several studies have explored the cascading impacts on elk foraging behavior and aspen extent. Researchers have monitored aspen stands in transects, but more research is needed to better understand the health and extent of aspen stands across the region, especially in the context of trophic cascades.

***Project Objectives:***

* Evaluate 1954 aspen extent from historical aerial imagery
* Refine the first term’s analysis of aspen extent by using accurate training points and a phenological approach to supplement the random forest model for 2021
* Generate comparison tables and maps to quantify and visualize changes in aspen stand extent for 1954 and 2021 with a focus on the 113 belt transects provided by the partners

***Previous Term:***

2022 Summer (GA) – Yellowstone Ecological Forecasting

**Partner Overview**

***Partner Organizations:***

|  |  |  |
| --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** |
| **National Park Service, Yellowstone National Park** | Dr. Daniel Stahler, Wildlife Biologist | End User |
| **Utah State University** | Dr. Daniel MacNulty, Professor;  Nicholas Bergeron, Researcher | Collaborator |
| **University of Wisconsin–Stevens Point** | Dr. Eric Larsen, Professor | Collaborator |

***Decision-Making Practices & Policies:***

The decision to reintroduce wolves to Yellowstone National Park in 1995 was made with little supporting information on how aspen stands might be affected. Since 1999, the team’s partners have monitored aspen stand regeneration primarily through *in situ* data collection, which is time- and resource-intensive and does not fully capture aspen stand extent. Researchers have used historical aerial imagery to measure changes in aspen canopy coverage but have not thoroughly combined this data with satellite imagery.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 8 OLI** | True Color Composites (RGB), Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), Tasseled Cap (Brightness, Greenness, Wetness) | Landsat 8 OLI spectral indices were used to estimate 2021 aspen stand extent through classification with both random forest and phenological approaches. |
| **Sentinel-2 MSI** | RGB, NDVI, EVI, Tasseled Cap (Brightness, Greenness, Wetness) | Sentinel-2 MSI spectral indices were used to estimate 2021 aspen stand extent through classification with both random forest and phenological approaches. |
| **PlanetScope** | RGB | PlanetScope imagery was used to obtain training and testing data for the 2021 aspen stand classification. |

***Ancillary Datasets:***

* USGS, Aerial Photography – Historical aerial imagery for digitization of 1954 aspen extent
* National Agriculture Imagery Program, Aerial Photography – 2019 aerial imagery used for georeferencing historical imagery
* Utah State University, Landcover Data – Point locations of a variety of landcover classes for training and testing the random forest model and calculation of NDVI thresholds for the phenological approach
* Utah State University and University of Wisconsin–Stevens Point, Aspen Belt Transects Shapefile and Data – Locations of 113 belt transects and aspen measurements for area of interest
* Yellowstone National Park, Boundary of Elk Wintering Range – Elk wintering range boundary for the spatial extent of the study region
* USGS 3DEP LidarExplorer, Digital Elevation Model (DEM) – Elevation data at 1/3 arc second for elevation and other terrain parameters used in the random forest model

***Modeling:***

* Random Forest (Contact: Dr. Marguerite Madden, University of Georgia) – Generate aspen classification

***Software & Scripting:***

* Google Earth Engine JavaScript API – Used to obtain and analyze satellite data through random forest and phenological approaches
* Esri ArcGIS Pro 3.0.2 – Used to georeference historical aerial imagery, digitize historical aspen extent, and produce maps

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **1954 Aspen Stand Extent Map** | N/A | Partners will use 1954 aspen extent maps to identify areas with persistent aspen. The partners will also use the data layers as covariates for future data models aimed at quantifying the indirect effects of wolves on aspen stand dynamics. | N/A |
| **2021 Aspen Stand Extent Map** | Landsat 8 OLI  Sentinel-2 MSI  PlanetScope | Partners will use 2021 stand extent maps of the Northern Elk Wintering Range to identify areas for further *in situ* data collection. The partners will also use these data layers as covariates for future data models aimed at quantifying the indirect effects of wolves on aspen stand dynamics. | N/A |
| **Aspen Stand Extent Comparison Tables and Maps** | Landsat 8 OLI  Sentinel-2 MSI  PlanetScope | Partners will use aspen stand extent comparison tables and maps to quantify and visualize 70 years of change in aspen stand extent. This information will be used to better understand the indirect effect of wolves on aspen stand dynamics. | N/A |

***Product Benefit to End User:***

Aspen monitoring in Yellowstone National Park could be improved to cover a greater land area and be more time-efficient. Analyzing historical data on aspen extent alongside satellite imagery derived from NASA Earth observations allows for a more comprehensive understanding of aspen regeneration in Yellowstone National Park. Having access to high-resolution maps highlighting change in aspen extent may allow partners to concentrate restoration efforts on key areas and increase understanding of how wolf reintroduction has impacted the landscape over time. The partners will use the results of this project to further understand how anthropogenic and ecological factors, including wolf reintroduction, have impacted aspen stand dynamics. Specifically, the partners aim to assess the connection between changes in aspen overstory and elk population dynamics in relation to wolf predation. Carnivore reintroduction is a controversial topic, and this project provides more context on the role of wolves in the Yellowstone ecosystem to inform resource management decision-making and improve public understanding.

**References**

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Hamilton, R., Megown, K., DiBenedetto, J., Bartos, D., & Mileck, A. (2009). Assessing aspen using remote sensing. RSAC-0110- RPT2. Salt Lake City, UT: U.S. Department of Agriculture Forest Service. Remote Sensing Applications Center. 8p. <https://www.fs.fed.us/rm/pubs_other/rmrs_2009_hamilton_r001.pdf>

Larsen, E. J., & Ripple, W. J. (2005). Aspen stand conditions on elk winter ranges in the northern Yellowstone ecosystem, USA. *Natural Areas Journal*, *25*(4), 326–338. <https://trophiccascades.forestry.oregonstate.edu/sites/trophic/files/Aspen_Stand_Conditions.pdf>