**Maine Ecological Forecasting II**

*Identifying Forest Cover and Assessing Federally Endangered Atlantic Salmon Habitat in Maine Using Earth Observations*

**Project Team**

***Project Team:***

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**Project Overview**

***Project Synopsis:***

In recent years, warming stream temperatures and land use land cover (LULC) change have exacerbated the effects of habitat loss that threaten the last remaining population of Federally Endangered juvenile Atlantic Salmon (*Salmo salar*) in the United States. The Maine Department of Marine Resources (DMR) and the Downeast Salmon Federation (DSF) are working to maintain this population and restore critical habitat. The NASA DEVELOP team used Earth observations to refine LULC maps from the previous term and highlight the relationship between temperature and forest and non-forest cover types as a means to inform salmon restoration efforts.

***Abstract:***

Major declines in Atlantic salmon (*Salmo salar*) populations have occurred alongside dam construction, shifting temperatures, and changing land use and land cover (LULC), restricting the last remaining wild population in the United States to Maine. In collaboration with the Maine Department of Marine Resources and the Downeast Salmon Federation, the NASA DEVELOP team utilized Earth observations to assess changes within critical salmon habitat. The team used the Landsat 5 Thematic Mapper (TM), Landsat 8 Operation Land Imager (OLI), Sentinel-2 MultiSpectral Instrument (MSI), and National Land Cover Database (NLCD) to refine historical LULC maps from 1985 to 2021. The team also used elevation data from the Shuttle Radar Topography Mission (SRTM) and IDRISI TerrSet Land Change Modeler to forecast LULC change to 2040. From Terra Moderate Resolution Imaging Spectroradiometer (MODIS) land surface temperature (LST) data, the team derived a time series, summer averages, and anomaly maps between 2000 and 2021. The team analyzed LST in relation to LULC classes, specifically forest cover type, and *in-situ* stream temperature from the Spatial Hydro-Ecological Decision System (EcoSHEDS). LULC trends from 1985 to 2021 revealed a net transition of coniferous forest to other classes, such as deciduous forest and developed land. The team found an association between warmer temperatures and a greater presence of developed and mixed forest classes per 10,000 acres across Maine. These visualizations and analyses will aid partners in identifying riparian locations with ideal or unfavorable habitat conditions to inform Atlantic salmon population recovery efforts.

***Key Terms:***

LULC, land surface reflectance, TerrSet, ecological forecasting, Landsat, MODIS, land surface temperature, critical salmon habitat

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

***Study Location:*** ME

***Study Period:*** 1985 – 2021

***Community Concerns:***

* Freshwater Atlantic salmon habitats are threatened by anthropogenic LULC changes including logging and development, which influence stream quality and aquatic habitat connectivity throughout watersheds in the state.
* Historic overfishing, pollution, and habitat loss due to dam construction over the past two centuries has resulted in the Gulf of Maine Distinct Population Segment (DPS) of Atlantic salmon becoming the last remaining wild population in the United States.
* Shifts in air and stream temperatures, changing precipitation patterns, and transitions in forest cover type within riparian areas directly affect water quality and nutrient availability, which have the ability to further constrain the current geographic range of Atlantic salmon.
* Communities throughout Maine historically benefited from Atlantic salmon and other fish species as both natural resources and regulators of stream water quality through movement and migrations. Atlantic salmon are part of a diadromous fish community which has seen an overall decline in species and abundance due to anthropogenic pressures, thus limiting benefits from such species.

***Project Objectives:***

* Refine LULC maps for characterizing land use and forest cover classification trends in critical Atlantic salmon habitat and forecast LULC changes to 2040
* Create forest cover maps delineating upland and wetland coniferous versus deciduous forest cover types
* Identify locations with warmer or cooler land surface temperature (LST) trends based on forest cover type
* Analyze the relationship between LST and forest cover type throughout the study region

***Previous Term:***

2021 Fall (GSFC) – Maine Ecological Forecasting

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Maine Department of Marine**  **Resources, Division of Sea-run**  **Fisheries and Habitat** | **Ernie Atkinson, Marine Resources**  **Scientist** | End User | Yes |
| **Downeast Salmon Federation** | **Dwayne Shaw, Executive Director** | End User | Yes |

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

The DMR and DSF are involved in Atlantic salmon habitat restoration and population recovery initiatives in Maine. The DMR aids in stream restoration efforts by identifying areas of thermal refuge and adding stream buffers in areas of degrading salmon habitat. The DSF is instrumental in maintaining Maine’s Distinct Population Segment (DPS) of Atlantic salmon through conservation hatcheries as well as habitat quality and salmon population surveys. This work informs habitat restoration efforts throughout the DPS critical habitat extent. Both the DSF and DMR aim to increase juvenile survival and adult salmon spawning in Maine’s rivers and improve the chances of successful oceanic migration and return to rearing streams. Neither the DMR nor the DSF currently use NASA Earth observations in their decision-making practices.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **Terra MODIS** | LST | LST was plotted over time and mapped across the study region. |
| **Landsat 5 TM** | Land surface reflectance | Land surface reflectance was used to generate  refined LULC maps. |
| **Landsat 8 OLI** | Land surface reflectance | Land surface reflectance was used to generate refined LULC maps. |
| **Sentinel-2 MSI** | Land surface reflectance | Land surface reflectance was used to identify forest cover type and validate LULC maps. |
| **SRTM** | Elevation, slope, and aspect | Elevation data and derivatives were used as driver variables for LULC forecasting. |

***Ancillary Datasets:***

* United States Fish & Wildlife Service (USFWS) National Wetlands Inventory – A combined water bodies and wetlands vector layer for comparison with team-generated land cover maps
* Spatial Hydro-Ecological Decision System (EcoSHEDS) Stream Temperature Database – *In-situ* stream temperature measurements for comparison with Terra MODIS LST
* United States Geological Survey (USGS) National Land Cover Database (NLCD) – LULC data for comparison with team-generated LULC maps and delineation of wetland forests
* Department of Administrative & Financial Services, Office of Information Technology, Maine Office of GIS – Driver variables for Idrisi TerrSet Land Change Modeler
* Esri, the USGS, and the National Atlas of the United States, USA National Atlas Rivers and Streams – Driver variables for Idrisi TerrSet Land Change Modeler

***Modeling:***

* TerrSet Land Change Modeler (Contact: Sean McCartney, Science Systems and Applications, Inc., NASA Goddard Space Flight Center) – Model LULC between 1985 and 2021, forecast LULC to 2040

***Software & Scripting:***

* Google Earth Engine API – Acquisition of satellite data
* Google Earth Pro – Validation of LULC maps
* R & RStudio – Generation of time series plots and analyses of LST and forest cover type
* Esri ArcGIS Pro 2.9.1 – Classification of LULC and produce temperature anomaly and forest cover time series maps

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Forest Cover Maps** | Landsat 5 TM  Landsat 8 OLI  Sentinel-2 MSI | Forest cover maps indicating  classification distinctions between coniferous versus  deciduous forest type will allow partners to focus on varying management decisions based on forest cover type and the effect it has on habitat quality. | I |
| **LULC and**  **Temperature**  **Anomaly Maps** | Terra MODIS  Landsat 8 OLI  Sentinel-2 MSI | LST anomaly maps displaying temperature deviations from the 2000–2010 baseline average for Maine can be overlayed with LULC maps to detect and visualize relationships between temperature and forest cover, providing partners with information that can be used to plan conservation efforts. | I |
| **Time Series of LST**  **(Based On Forest**  **Cover Type)** | Terra MODIS  Landsat 8 OLI  Sentinel-2 MSI | LST plots and analyses will provide the partners with information on temperature through time in relation to coniferous versus deciduous forest cover over the study area. | I |
| **Refined Past,**  **Current, and**  **Forecasted LULC**  **Maps (Forecasted to**  **2040)** | Landsat 5 TM  Landsat 8 OLI  Sentinel-2 MSI  SRTM | Refined LULC maps will provide detailed information on land use surrounding critical salmon habitat between the years 1985–2021. LULC maps that are forecasted into the year 2040 will provide additional insight into potential land use trends that could affect salmon habitat in the future. | I |

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

The end products from this project will provide the DMR and DSF with a customized map of LULC types for select years within the state of Maine. The forecasted LULC maps for 2040 will allow the partners to consider land use trends and focus their habitat restoration efforts in the future. In addition, the relationship between land surface temperature and forest cover type will help inform the partners on which specific LULC types could be contributing to LST and stream temperature warming throughout the critical habitat extent. Overall, this project will allow the partners to have a comprehensive look into Earth observations and how they can incorporate these tools into their habitat monitoring, salmon population recovery, and habitat conservation projects.

***Project Continuation Plan:***

Refined LULC maps and LULC maps forecasted to 2040 will be handed off to the third term team. These maps include analysis of forest cover type in relation to anomalous land surface temperature and precipitation. This information will provide a framework to monitor habitat variables throughout the current range of Atlantic salmon, thus informing on-going and future salmon habitat restoration efforts. These end products and methods can be directly applied to the third and final DEVELOP team’s development of a workshop that will give the partners tools to integrate Earth observations into their future projects.

**References**

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