**Maine Ecological Forecasting**

*Using NASA Earth Observations to Assess Federally Endangered Atlantic Salmon Habitat in Maine*

**Project Team**

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**Project Overview**

***Project Synopsis:***

Climate patterns in Maine’s critical habitat for Federally Endangered juvenile Atlantic salmon (*Salmo salar*) are shifting, threatening salmon health and population recovery. The State of Maine Department of Marine Resources (DMR) and the Downeast Salmon Federation (DSF) are working to restore habitat and recover populations of the last wild Atlantic salmon in the United States. The NASA DEVELOP team applied and tested Earth observations to monitor trends and anomalies in temperature and precipitation over time. The team also created land use land cover (LULC) maps and assessed land cover changes to help inform the DMR and DSF management and recovery programs.

***Abstract:***

Atlantic salmon (*Salmo salar*) is a species of anadromous fish that was historically prevalent throughout the New England region. Overfishing and habitat loss caused a severe decline in the salmon population, restricting North America’s remaining wild Atlantic salmon to rivers in Maine. Land use and land cover (LULC) change and factors associated with temperature and precipitation are important for understanding the suitability of freshwater habitat for juvenile salmon. In collaboration with the Maine Department of Marine Resources and the Downeast Salmon Federation, the team utilized NASA Earth observations to aide partners in understanding how these factors change in relation to critical salmon habitat. Landsat 5 Thematic Mapper (TM) and Landsat 8 Operational Land Imager (OLI) imagery was analyzed to assess changes in LULC between 1985 and 2021. Terra Moderate Resolution Imaging Spectroradiometer (MODIS) and Integrated Multi-satellite Retrievals for Global Precipitation Measurement (GPM IMERG) data were used to determine land surface temperature and precipitation, respectively; between 2000 and 2020. Lastly, temperature and precipitation anomaly maps visualized deviation from the 20-year climatic average for each pixel. LULC analysis for 1985 to 2020 showed a loss of forest cover throughout critical salmon habitat although gains in forested area were also observed. Assessment of mean summer land surface temperature revealed an increase in temperature from 2000 to 2020 and anomaly maps highlighted areas experiencing abnormally high or low summer precipitation and temperature. These results and the underlying data were packaged for the partner organizations to inform future conservation efforts.

***Key Terms:***

satellite remote sensing, salmonid fisheries management, land use land cover change, land surface temperature, forecasting, critical salmon habitat

***National Application Areas Addressed:*** Ecological Forecasting, Water Resources

***Study Location:*** ME

***Study Period:*** January 1985 – December 2021

***Community Concerns:***

* Atlantic salmon are native throughout New England, however, their population declined due to dam construction, overfishing, pollution, and logging practices. The Gulf of Maine Distinct Population Segment is the only remaining wild population in the United States and is federally protected under the Endangered Species Act.
* Changing air temperature and shifting precipitation patterns influence stream temperature and flow, which can impact the development, growth, and performance of salmon. Land cover changes stemming from land use practices such as logging, agriculture, and urban development can negatively impact Atlantic salmon habitat and alter the ability of salmon to access stream habitat.
* Atlantic salmon migrations facilitate nutrient cycling and act as major carbon fluxes. Declines in salmon have reduced their functional role in contribution to the ecosystem services provided by marine and freshwater environments in Maine.
* Atlantic salmon have significant cultural and historical value among communities in the region and were once contributors to subsistence, commercial, and recreational Maine fisheries. Reduced populations limit the opportunities for Atlantic salmon to provide these services in Maine.

***Project Objectives:***

* Generate time series of temperature and precipitation throughout the state of Maine for the years 2000 to 2020
* Produce statewide anomaly maps that display temporal variation in precipitation and temperature from 2000 to 2020
* Create maps of and assess changes in LULC in the state of Maine between 1985 and 2021

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **The State of 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 identifies areas of thermal refuge for juvenile Atlantic salmon and areas of degrading salmon habitat that should be protected. Their river assessments are also used to increase the number of stream buffers in the area. The DSF focuses their efforts on conservation hatcheries, habitat restoration, and replenishing Atlantic salmon stock. They closely monitor water level, temperature, and food availability through *in situ* observations to determine habitat quality. The goal of DSF and DMR is to increase juvenile survival and adult salmon spawning in Maine’s rivers and improve the chances of salmon making their way to the ocean and back. 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** | **Parameters** | **Use** |
| **Terra MODIS** | Land Surface Temperature | MODIS data were used for generating plots of temperature over time and maps displaying temperature across the landscape. |
| **Landsat 5 TM** | Land Surface Reflectance, Land Surface Temperature | Landsat 5 images were used for generating plots and maps of temperature over time. Land surface reflectance was used to create LULC maps. |
| **Landsat 8 OLI** | Land Surface Reflectance, Land Surface Temperature | Landsat 8 images were used for generating plots and maps of temperature over time. Land surface reflectance was used to create LULC maps. |
| **GPM IMERG** | Precipitation (algorithm to predict interpolated values) | GPM IMERG was used to acquire data for generating plots of precipitation over time and maps displaying precipitation across the landscape. |

***Ancillary Datasets:***

* DMR Salmon Survey Data – Provide known locations of Atlantic salmon in Maine streams and rivers
* USGS National Land Cover Database (NLCD) – Provide foundational guide for drafting a classification scheme for LULC maps

***Modeling***

* DMR Wright Model (POC: Ernie Atkinson, DMR) – Atlantic salmon habitat suitability model, used to identify keystreams and rivers in Maine

***Software & Scripting:***

* ArcGIS Pro 2.8.3 – Map and visualize temperature, precipitation, and LULC variables
* Google Earth Engine – Acquire satellite imagery, temperature, and precipitation data from multiple sensors and satellites
* RStudio 1.3.1073 – Generate time series plots of temperature and precipitation

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Time Series of LST and Precipitation** | Terra MODIS GPM IMERG | Plots of mean summer LST and precipitation will provide the partners with a record of how these variables have changed in the study region from 2000 to 2020. | I |
| **LST and Precipitation Maps** | Terra MODIS  GPM IMERG | These annual maps will provide the partners with a deeper understanding of how LST and precipitation have changed spatially and temporally from 2000 to 2020. | I |
| **LST and Precipitation Anomaly Maps** | Terra MODIS  GPM IMERG | Maps of LST and precipitation anomalies across the Maine landscape will indicate anomalously warm and anomalously dry summer conditions in the study region. These maps can be used by the partners to identify suboptimal habitat conditions for salmon. | I |
| **Past, Current LULC Maps & LULC Change Map** | Landsat 5 TM  Landsat 8 OLI | These maps visually display land cover types in 1985, 2003, and 2021 as well as the change between years. These will provide detailed information on land use trends in and around critical salmon habitat. | I |
| **True Color Composites** | Landsat 5 TM  Landsat 8 OLI | True color imagery will serve as a reference for LULC maps. | I |

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

The end products from this project will provide the DMR and the DSF with a comprehensive understanding of the spatial and temporal variations of temperature and precipitation in the study area. In addition, LULC maps showing past and present land cover, and the changes between dates, can help the end users make informed decisions regarding projects and policies. Finally, using NASA Earth observations in conjunction with *in situ* observations can provide a holistic perspective into current projects or conservation efforts for a more comprehensive monitoring of salmon recovery and habitat conservation.

***Project Continuation Plan:***

LULC maps generated in the first term will be used to forecast land cover change through 2040 using TerrSet Land Change Modeler. Additionally, the second term team will update the classification scheme to enable identification of coniferous and deciduous wetland forest for current and forecasted LULC maps. Forest type identification will be spatially referenced to cooler temperature areas and will allow for exploration of the effects of forest type on water quality and nutrient flow dynamics in salmon habitat restoration efforts.

**References**

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