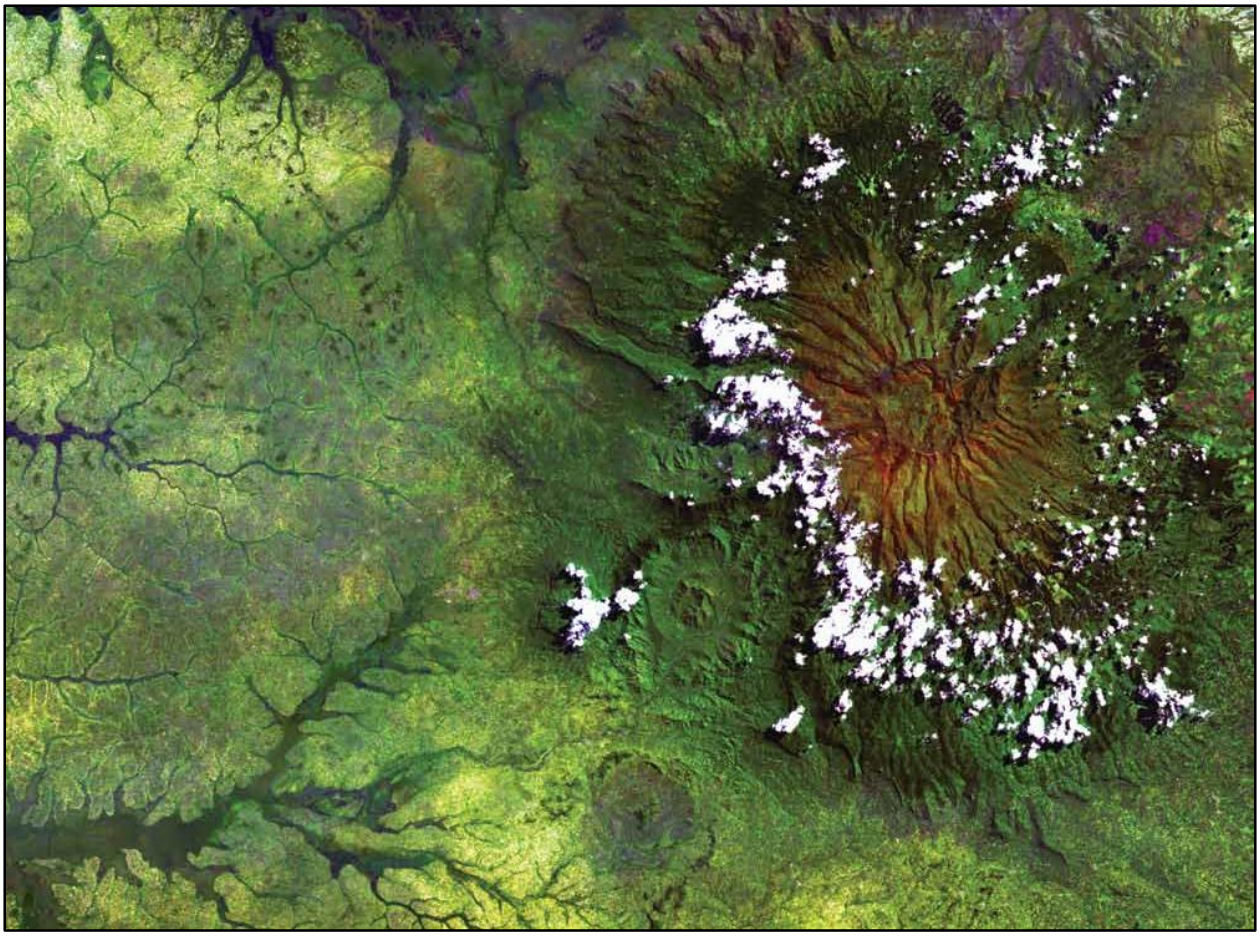
DEVELOP National Program

Ecological Forecasting Project Proposals

Summer 2015



Proposals Snapshot

1. Ethiopia Ecological Forecasting: Mapping Fire History for Habitat Conservation in Ethiopia's Galama Mountains, using a Time Series of Landsat Data (Fort Collins)
Objective: Quantify fire occurrence and distribution in the unique, high-altitude shrublands of Ethiopia's Galama Mountains by mapping and modeling burned areas and vegetation health from 1985-2014.

2. Maryland Ecological Forecasting: Utilizing NASA Earth Observations to Monitor and Strengthen the Survivorship of Maryland's Sea Turtles (Goddard)
Objective: Map water surface temperatures, near shore temperatures, and algal bloom conditions along Maryland's coasts to complete a historical analysis correlating these biophysical parameters to geo-referenced turtle mortality data.

3. North Carolina Ecological Forecasting: Evaluating the Application of NASA Earth Observations to Rapidly Detect Change in Wetland Types at a Regional Scale (Langley)
Objective: Evaluate how open-source imagery from Landsat 8 and other remote sensing platforms can be applied in a multi-resolution strategy to more rapidly detect and evaluate changes in wetland types at regional (broad landscape) scales.

4. Texas-Arizona Ecological Forecasting: Utilizing NASA Earth Observations to Monitor and Manage Ocelot Habitat Loss (Marshall)
Objective: Track the change in ocelot habitat from 1980 to the present throughout southeast Texas and south Arizona and determine how urbanization, road development, habitat loss, habitat fragmentation, and other barriers have had an impact.

5. Mississippi Ecological Forecasting: Using NASA Earth Observations to Locate Potential Habitat for the Dusky Gopher Frog (Stennis)
Objective: Use NASA Earth observation data to locate potential breeding sites suitable for the endangered dusky gopher frog (Lithobates sevosus), a species currently only found in two small ponds within the DeSoto National Forest of Harrison County, Mississippi.

6. Ocmulgee Ecological Forecasting: Utilizing NASA's Earth Observations for Forecasting Land Use Change and Wildlife Disturbances along the Ocmulgee River Corridor (UGA)
Objective: Analyze the effects of changing conditions on the wildlife and fisheries in the Ocmulgee River corridor with a focus on endangered native species.

7. Southeast US Ecological Forecasting: Utilizing NASA Earth Observations and Proximal Remote Sensing for Mapping the Spatio-temporal Distribution of *Hydrilla* (UGA)
Objective: Develop a multi-platform approach for mapping the spatial and temporal distribution patterns of Hydrilla sp. sp. in several water bodies in Georgia and Florida.

Partners Snapshot

Local Partners

- Henry County Water Authority (End-user/Partner, POC: Ken Presley, Assistant Reservoir Manager)
- Albemarle-Pamlico National Estuary Partnership (APNEP; Partner and Boundary Organization, POC: Jim Hawhee, Policy and Engagement Manager, Dean Carpenter, Program Scientist)

State Partners

- Maryland Department of Natural Resources (MDDNR): Marine Mammal and Sea Turtle Stranding Program (End User/Partner, POCs: Amanda Johnson, Program Coordinator; Dr. Cindy Driscoll, Director of the Fish & Wildlife Health Program at the MDDNR)
- Georgia Department of Natural Resources (Partner/End-User, POC: Dan Forster, Director of Wildlife Resources Division; Thomas Litts, Special Project Operations Manager)
- Texas Department of Transportation (Collaborator/End-User, POC: Dr. John Young, Jr., Environmental Specialist)

Federal Partners

- USDA Forest Service: DeSoto Ranger District (Boundary Organization, POC: Ed Moody, Wildlife Biologist)
- US Fish and Wildlife Service (Collaborator/End-User, POC: Linda LaClaire, Wildlife Biologist)
- US Army Corps of Engineers (Boundary Organization, POC: Danny Hartley, Wildlife Biologist)

International Partner

- Secretaria de Medio Ambiente y Recusos Naturales (SEMARNAT) (Collaborator/Boundary Organization/End-User, POC: Dr. Arturo Caso, Area Director)

NGO Partners

- The Murulle Foundation (TMF) (End-User, Partner, and Boundary Organization, POC: Nicholas Young, Secretary)
- J.W. Jones Ecological Research Center (Partner, POC: Dr. Stephen W. Golladay, Associate Scientist)
- National Parks Conservation Association (Potential End-User, POC: Dr. Chris Watson, Senior Program Manager)
- The Nature Conservancy (Collaborator/End-User, POC: Jim Lee, Biologist)
- Pittsburgh Zoo & PPG Aquarium (Collaborator/Boundary Organization, POC: Ken Kaemmerer, Ocelot SSP Chair & Dr. Josh Gaspard, Director of Science and Conservation)
- The Denver Zoo (Collaborator/End-User, POC: Nanette Bragin, GIS Conservation Biologist)
- South Texas Refuge Complex (Collaborator/End-User, POC: Mitch Sternberg, Zone Biologist-South Texas Gulf Coast)

Academic Partners

- Colorado State University, Natural Resource Ecology Laboratory (NREL) (End-User, Partner), POC: Nicholas Young, Research Associate)
- Texas A&M University-Kingsville, Caesar Klegerg Wildlife Research Institute (Collaborator/End-User/Boundary Organization, POC: Michael Tewes, Frank D. Yturria Endowed Chair in Wild Cat Studies and Regents Professor)

Private Company Partners

- Georgia Power (End-user/Partner, POC: Anthony Dodd, Environmental Specialist)

Letters of Support

- MSFC Texas-Arizona Eco Forecasting – Pittsburgh Zoo & PPG Aquarium, Kenneth R. Kaemmerer, Ocelot SSP Chair and USFWS Ocelot Recovery Team
- MSFC Texas-Arizona Eco Forecasting – Texas Department of Transportation, Carlos Swonke, Director of Environmental Affairs Division
- MSFC Texas-Arizona Eco Forecasting – Cincinnati Zoo and Botanical Gardens, Shasta R. Bray, Ocelot Species Survival Plan Education Advisor and Interpretive Media Manager
- UGA Georgia Eco Forecasting – J.W. Jones Ecological Research Center – Dr. Stephen W. Golladay, Associate Scientist

Project Proposals

1. Ethiopia Ecological Forecasting

Mapping Fire History for Habitat Conservation in Ethiopia's Galama Mountains, using a Time Series of Landsat Data

Objective:

This project will quantify fire occurrence and distribution in the unique, high-altitude shrublands of Ethiopia's Galama Mountains. Burned areas will be mapped and summarized over 29 years, using Landsat Thematic Mapper and Operational Land Imager data from 1985-2014 and the LandTrendr model.

Community Concern:

The Galama Mountains are part of the Arsi mountain chain in central Ethiopia and are dominated by Afro-alpine grasslands and *Erica* spp. shrublands. They are home to a number of flora and fauna including leopard, klipspringer, Ethiopian wolf, and the endemic mountain nyala; a spiral horned antelope listed as endangered by the International Union for Conservation and Nature (IUCN). This species relies on mature *Erica* spp. shrubland and avoids contact with humans and livestock. Although illegal, the local communities practice intentional burning of the *Erica* spp. shrub to promote grasslands, which in turn increases forage for their livestock. This practice reduces the critical habitat mountain nyala rely on and increases soil erosion. Over the past quarter century, there have been various national and regional efforts to establish conservation areas with limited and varying success. The Murulle Foundation (TMF) has been involved with conservation efforts in the Galama Mountains since 2001, and has been working to map critical habitat for the mountain nyala while engaging the local communities to establish conservation areas. NASA products can be used to map and quantify previous fire occurrence and extent, which—in combination with other products developed by TMF—will inform the Murulle Foundation to help identify priority conservation areas.

End-Users/Partners/Boundary Organizations:

The Murulle Foundation (TMF) (End-User, Partner, and Boundary Organization, POC: Nicholas Young, Secretary)

Natural Resource Ecology Laboratory (NREL) at Colorado State University (End-User, Partner), POC: Nicholas Young, Research Associate)

TMF was a partner on a previous NASA DEVELOP project, and there continues to be a strong relationship between NREL scientists, TMF, and NASA DEVELOP. TMF is aware of this project and has been in communication with the potential DEVELOP team and science advisors. The need for a map showing historical fire history in the Galama Mountains over the last 29 years has emerged as a desired product for both the Natural Resource Ecology Laboratory and TMF. These groups currently work together, communicate frequently, and share data. The Murulle Foundation will use the fire history map to validate field data and to identify old growth *Erica* spp. shrubland. This will help identify conservation priority areas that will be communicated to local communities and managers of existing forest reserves. The Natural Resource Ecology Laboratory will use the fire history map to develop land use/ land cover change models to provide insights into the relationship between *Erica* spp. health and fire history.

Decision Making Process:

As a 501(c)(3) non-profit, The Murulle Foundation focuses on fostering participatory grassroots projects that build enduring coexistence of people and ecosystems. TMF has worked with multiple land managing organizations in Ethiopia, including the Ethiopian Wildlife Conservation Authority, the Ministry of Forestry, and Frankfurt Zoological Society, and will use the map of fire

history to bring attention to the complex human-environment interactions in the Galama Mountains.

TMF has used Landsat data for basic land cover mapping in the past, but is currently relying on limited field observation regarding Erica *spp.* fires. Maps of the region's fire history will enable TMF to relate spatial and temporal patterns of burning to the increased human activity and land use change, and will guide future sampling and conservation efforts. Furthermore, the maps will be used to develop mountain nyala habitat suitability models.

Earth Observations

Platform	Sensor	Geophysical Parameter
Landsat 5	Thematic Mapper (TM)	Burned Area
Landsat 8	Operational Land Imager (OLI)	Burned Area
Aqua/Terra	Moderate Resolution Imaging Spectroradiometer (MODIS)	Burned Area
Space Shuttle	Shuttle Radar Topography Mission (SRTM)	Elevation

NASA Earth Observations to be Highlighted:
The extensive historic record of data captured by the Landsat missions, in combination with advanced change detection models, provides an opportunity to quantify and map fire history disturbance in remote and largely undocumented regions. Landsat's 29 years of 30 m satellite imagery data will allow the team to identify and quantify historical fire occurrences in the Galama Mountains.

The MCD45A1 Aqua/Terra MODIS fire product developed by the Land Processes Distributed Active Archive Center will be used to corroborate and provide further confidence in the Landsat-derived results.

The recent release of 30 m SRTM data for Ethiopia will enable precise delineation of the distinct elevation-based life zones that exist in the eastern Ethiopian highlands. These will support focused modeling within ecologically similar areas.

Ancillary Datasets:
Spatial extents of protected/managed areas in Galama (TMF, NREL)

Models:
Landsat-based Detection of Trends in Disturbance and Recovery (LandTrendr) (POC: Robert Kennedy, Boston University)

Decision Support & Analyses:

Proposed End Products	Decision Impacting	Current Partner Tool/Method
Fire Frequency and Extent Map	Focus management of *Erica* spp. based on fire history, inform habitat suitability of mountain nyala	Field surveys, classification models

Fire Frequency and Extent Map – This map will include multiple raster layers showing the date and magnitude of disturbances across the Galama Mountains. Landsat 5 TM and Landsat 8 OLI imagery from 1985-2014 will be used to develop the LandTrendr model.

Project Details:

National Application Area Addressed: Ecological Forecasting, Disasters
Source of Project Idea: This project was introduced by the end-user (The Murulle Foundation). Through field observations, members of the Murulle Foundation started making connections between fire occurrence, Erica spp. health, and mountain nyala abundance and distribution. In an effort to empirically and scientifically support these observations, The Murulle Foundation was interested in taking advantage of long-term remote sensing products that NASA provides to help address this problem.

Advisor: Paul Evangelista (NREL, Colorado State University)
# of Participants Requested: 4

Project Timeline: 1 Term: 2015 Summer
Study Location: Central Ethiopia, including the Arsi highlands and surrounding lowlands (Landsat Scene Path 168 Row 55)
Period being Studied: 1985 - 2014

Previous Related DEVELOP Work:
Colorado Agriculture
Reconstructing Forest Harvest History Using the Landsat Time Series
Spring 2015 (Fort Collins)

Notes:

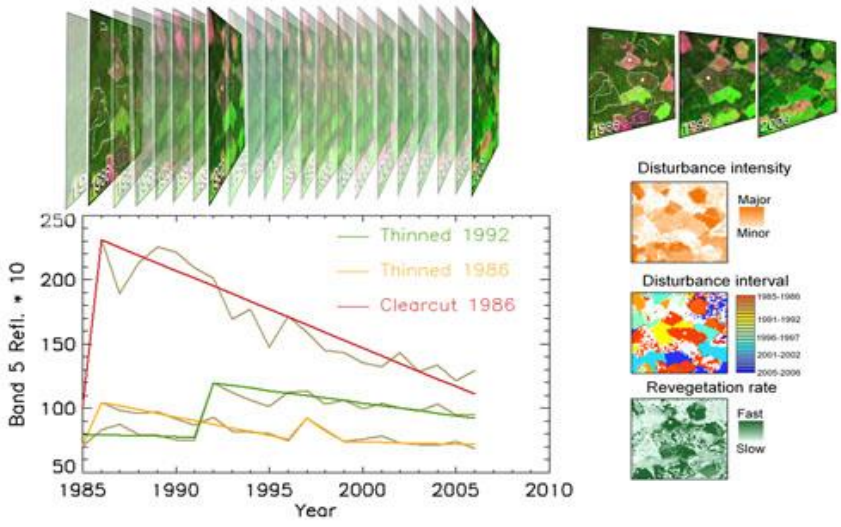


Figure 1. This figure shows how LandTrendr tracks forest disturbances using the trajectory of three pixels from Landsat images from 1985- 2006 as an example. Intense, short disturbances correspond to a clear cut, while moderate, short disturbances indicate thinning. Three of the outputs are shown on the right: disturbance intensity, disturbance interval, and revegetation rate. (http://landtrendr.forestry.oregonstate.edu/)

2. Maryland Ecological Forecasting

Utilizing NASA Earth Observations to Monitor and Strengthen the Survivorship of Maryland's Sea Turtles

Objective:
This project will map water surface temperatures, near shore temperatures, and algal bloom conditions along Maryland's coasts to complete a historical analysis correlating these biophysical parameters to geo-referenced turtle mortality data. In addition, a climate change

analysis will be performed and future climate forecasts will be made to serve as a proxy for sea turtle nest site shifts.

Community Concern:

Since 1991, over 500 sea turtle carcasses have been discovered and reported in the Chesapeake Bay and along the Delmarva Peninsula shores of the Atlantic Ocean. The majority of these sea turtles mortalities are loggerheads and leatherbacks, occasionally a Kemp's ridley or an even rarer green sea turtle will be found. All species of sea turtles in United States waters are listed under the U.S. Endangered Species Act. While most of these deaths can be attributed to boat strikes and aquatic interactions, the Maryland Department of Natural Resources Marine Mammal and Sea Turtle Stranding Program recognizes algal blooms and extreme weather as an additional cause of marine animal and sea turtle fatalities. Excessive or toxic algal blooms and shifting water and near-shore temperatures may be putting sea turtles at elevated risk. Revealing this relationship would be important in ensuring the longevity and success of sea turtles in Maryland waters. In addition, changing climatic conditions have resulted in a northern shift in sea turtle nest site preference. Observing current and predicting future climate scenarios will help conservationists preserve suitable sites and encourage successful hatchings.

End-Users/Partners/Boundary Organizations:

Maryland Department of Natural Resources (MDDNR): Marine Mammal and Sea Turtle Stranding Program (End User/Partner, POCs: Amanda Johnson, Program Coordinator; Dr. Cindy Driscoll, Director of the Fish & Wildlife Health Program at the MDDNR)

Former DEVELOP Center Lead Sam Weber visited Amanda Weschler and Dr. Cindy Driscoll on August 21, 2014 at the MDDNR office in Oxford, Maryland, to discuss the project idea and decision support tools that would be most beneficial to the Stranding Program. The partner is interested in seeing if there are any strong correlations between biophysical parameters within the Chesapeake Bay and Atlantic shore of Maryland that could predict above normal sea turtle mortality (average is about 24 deaths a year). In addition, climate change is causing a northern shift in sea turtle nesting locations, and a better understanding of future climatic trends could help conservation and hatching assistance efforts. Their office is about an hour away from Goddard, and they were open to meeting with a DEVELOP team a few times during the term, during which they could discuss the project, observe a sea turtle necropsy, and hand off decision support tools.

Decision Making Process:

Currently the MDDNR Marine Mammal and Sea Turtle stranding program does not use any remote sensing in their management practices for finding deceased turtles, predicting conditions that will increase mortality rates, or locating and predicting future nest sites. Both mortality and nest site locations are reported to the MDDNR by other agencies and concerned citizens. During a necropsy, the cause of death is determined to be due to a disease, infection, external trauma, age, or environmental conditions. However, without knowing the relationship and extent of temperature and algal blooms, the MDDNR is not able to conclusively determine if environmental conditions may have stressed or neurologically impaired the turtle. In relation to nest sites, they are marked off and protected from passerbys and wildlife after a report is received. The MDDNR currently has no way of predicting future locations of nest sites in order to prepare for future breeding seasons.

Earth Observations:

Platform	Sensor	Geophysical Parameter
Aqua	AMSR-E	Water Surface Temperature
Aqua & Terra	MODIS	Chlorophyll-a, Land Surface Temperature

Suomi NPP	VIIRS	Water Surface Temperature
Landsat 5, 7, 8	TM, ETM+, OLI, TIRS	Chlorophyll-a, Land and Water Surface Temperatures

NASA Earth Observations to be Highlighted:
Using Aqua, Terra, Suomi NPP, and Landsat temperature detecting sensors, the MDDNR can identify anomalous water temperatures that may have attributed to the death of sea turtles. Aqua, Terra, and Landsat will be used to measure chlorophyll *a,* which is associated with algal blooms, to analyze the relationship between algal conditions and the death of sea turtles. This will be useful for improving sea turtle hatching success, reducing deaths, and potentially recovering carcasses faster, which would result in better preserved specimens and a more comprehensive necropsy. Using the temperature imagery, a historical climate map indicating seasonal nesting location temperatures can be used to predict how changing temperatures can affect turtle nesting sites. By forecasting the location of future nesting sites, the MDDNR can work with neighboring states to acquire land and a work force to prepare for future breeding seasons.

Ancillary Datasets:
Sea Turtle Mortality data, provided by the MDDNR
Beach Temperature Probe data, provided by MDDNR
NOAA Chesapeake Bay Interpretative Buoy System
National Center for Atmospheric Research (NCAR) Community Climate System Model (CCSM3) projections

Models:
NCAR CCSM3 IPCC Climate Change Commitment Scenario Ensembles

Decision Support Tools & Analyses:

Proposed End Products	Decision Impacts	Current Partner Tool/Method
Sea Turtle Stranding Correlation Analysis	Prepare personnel for periods of increased turtle mortality	Incoming reports from other agencies and citizens
Near-Shore Climatic Change Analysis	Protect future nest site locations, prepare and dispatch personnel teams to future locations	No predictive processes to identify future sites

Sea Turtle Stranding Correlation Analysis – Correlate sea turtle death data from 1991 to present with algal bloom activity (as measured using chlorophyll *a*) and near shore surface temperature near the time of death for all mortality incidents. Multiple data products have temperature and chlorophyll-*a* information, the product used will be dependent on the time of the mortality incident, since the days directly proceeding the incident are the most crucial. A correlation analysis will indicate if any, either, or both variables are linked to sea turtle deaths.

Near-Shore Climatic Change Analysis – Determine average temperatures along the Maryland coast during sea turtle nest creation for the past 15 years. Using spatial statistics, determine if nest site locations have statistically changed through time and if so, use correlation analyses to see if the changes are due to fluctuating temperatures. With this information, use the IPCC projected temperature regimes in this area to forecast its effect on sea turtle nesting.

Project Details:
National Application Areas Addressed: Ecological Forecasting, Oceans

Source of Project Idea: Former DEVELOP Center Lead Sam Weber reached out to local state and federal agencies, including the Maryland DNR. He visited Amanda Weschler and Dr. Cindy Driscoll on August 21, 2014 at their office to discuss project ideas.

Advisor: John Bolten (NASA GSFC)
# of Interns Requested: 3

Project Timeline: 1 Term: 2015 Summer
Study Location: Chesapeake Bay and Atlantic Coast of Maryland
Period being Studied: September 1991 – present, climate projected dates 2020, 2030, 2040, 2050

3. North Carolina Ecological Forecasting

Evaluating the Application of NASA Earth Observations to Rapidly Detect Change in Wetland Types at a Regional Scale

Objective:
This project aims to evaluate how open-source imagery from Landsat 8 and other remote sensing platforms can be applied in a multi-resolution strategy to more rapidly detect and evaluate changes in wetland types at regional (broad landscape) scales.

Community Concern:
Despite the profound ecological importance of wetland conditions in the Albemarle-Pamlico estuarine system, data and resource limitations have prevented the Albemarle-Pamlico National Estuary Partnership (APNEP) from developing an indicator of wetlands extent. Active wetland monitoring programs by APNEP partners exist but have limited utility for ecosystem-based management in the Albemarle-Pamlico region. NOAA's Coastal Change Analysis Program (C-CAP) assigns a variety of coastal land cover classifications using satellite imagery, including various wetland cover types. However, the extent of this effort does not include the upper portion of the Albemarle-Pamlico watershed, data is acquired on a five-year cycle and is often subject to multi-year delays between data collection and the release of digital products that are of use to managers.

End-Users/Partners/Boundary Organizations:
Albemarle-Pamlico National Estuary Partnership (APNEP; Partner and Boundary Organization, POC: Jim Hawhee, Policy and Engagement Manager, Dean Carpenter, Program Scientist)

Partnership with APNEP has been growing since the fall 2014 term. Jim Hawhee proposed this project with the intention of applying the methodology to all land cover types in the Albemarle-Pamlico region. The methodologies can also applied to all National Estuary Programs (28 total) across the United States, who would like to more rapidly and accurately evaluate wetland extent trends within their watershed. APNEP staff is well-positioned to disseminate the results of this project to other programs and consult with them regarding the utility of the effort for environmental management purposes.

Decision Making Process:
Currently, the method for classifying land cover is through the use of C-CAP, which applies a semi-automated algorithm with Landsat imagery (Classification and Regression Tree [CART] analysis) to characterize land cover types. The project team would evaluate this algorithm, make improvements if possible, and apply it to recent Landsat 8 data to evaluate the current extent of various wetland classes throughout the Albemarle-Pamlico region. If sufficient project

resources are available, the algorithm would be applied to historic Landsat data as well, providing the basis to conduct a spatial trend analysis for wetlands throughout the Albemarle-Pamlico region. The use of open-source imagery from other platforms to compliment Landsat data would be evaluated as well. The methodology and protocol for routinely evaluating and updating new Landsat information to periodically characterize wetland extent through the Albemarle-Pamlico watershed would be of great benefit to APNEP.

Earth Observations:

Platform	Sensor	Geophysical Parameter
Landsat 7	ETM+	Land cover
Landsat 8	OLI/TIRS	Land cover

NASA Earth Observations to be Highlighted:
Landsat 7 and 8 imagery will be used primarily to create land cover classification for the Albemarle-Pamlico watershed with a focus on wetlands. In conjunction with C-CAP data, the imagery from Landsat 7 and 8 can help determine whether open access data can be substituted for higher-resolution data for use by national estuary programs nationwide.

Ancillary Datasets:
- NOAA's Coastal Change Analysis Program (C-CAP)
- Ground truth surveys (provided by partners)

Models:
Random Forest land cover classification model (POC: Daniel Jenson, Geoinformatics YP)

Decision Support Tools & Analyses:

Proposed End Products	Decision Impacting	Current Partner Tool/Method
Historic and Current Wetland Extent Maps	APNEP assessment of the historical trends in wetland extent, which impact future conservation policies in the region	C-CAP data
Map of Future Wetland Extents	Preparation of policy changes to preserve wetlands in areas of forecasted loss	None

Historic and Current Wetland Extent Maps – Through the use of a Random Forest model, the historic and current wetland extent will be mapped for the regions in the Albemarle-Pamlico watershed. These maps, along with the methodologies used to create them, were requested by the partner organization, APNEP.

Map of Future Wetland Extents – Through the use of Land Change Modeler in ArcGIS, the future extents of wetlands in the Albemarle-Pamlico watershed with be generated. This map with provide the partners with information that can be used in policy-making to ensure that the wetlands are preserved.

Project Details:
National Application Areas Addressed: Ecological Forecasting, Climate
Source of Project Idea: This project idea was proposed by Jim Hawhee from APNEP through his meetings with APNEP's science team.

Advisor: Dr. Kenton Ross (DEVELOP National Program)
# of Participants Requested: 4

Project Timeline: 2 Terms: 2015 Summer to 2015 Fall
Study Location: North Carolina
Period being Studied: 1990 - 2015

Previous Related DEVELOP Work:
Great Lakes Climate: Monitoring the Impacts of Climate Change and Decreasing Water Levels on Wetlands in the Great Lakes Region of North America - Spring 2015 (LaRC)

Virginia Agriculture II: Providing a Quantitative Tool based on NASA Earth Observations for Assessing Virginia's Growing Agriculture Economy - Spring 2015 (Wise County)

Multi-Term Objectives:

- **Term 1 (Proposed Term)** – Create the historic and current wetland extent maps of the Albemarle-Pamlico watershed using Random Forest classification method. Use the Land Change Modeler tool to predict the future wetland extents in the area.

4. Texas-Arizona Ecological Forecasting

Utilizing NASA Earth Observations to Monitor and Manage Ocelot Habitat Loss

Objective:
The objective of this project is to track the change in ocelot habitat from 1980 to the present throughout southeast Texas and south Arizona and determine how urbanization, road development, habitat loss, habitat fragmentation, and other barriers have had an impact. This will be accomplished by determining the locations of the ocelot habitat; how much damage urban development, agriculture, and road development are causing; and the rate of decrease of the ocelot habitat by utilizing the Landsat satellite series, Terra, and Aqua.

Community Concern:
An ocelot (*Leopardus pardalis*) is a type of cat that can be found from Texas to Northern Argentina in both humid tropical rainforests and dry scrublands. Currently, it is estimated that fewer than 100 ocelots remain in the United States (US Fish and Wildlife Service). Ocelots need at least seven miles of dense vegetation in order to hunt for prey. Due to urban development, agricultural purposes, road development, and other barriers, such as fences, that cause inbreeding, the ocelot habitat is shrinking causing the separation of habitat patches. This has caused the ocelot to become an endangered species. Mapping of the ocelot habitat is required to help monitor and manage the area.

End-Users/Partners/Boundary Organizations:
Pittsburgh Zoo & PPG Aquarium (Collaborator/Boundary Organization, POC: Ken Kaemmerer, Ocelot SSP Chair & Dr. Josh Gaspard, Director of Science and Conservation)
Texas A&M University-Kingsville, Caesar Klegerg Wildlife Research Institute (Collaborator/End-User/Boundary Organization, POC: Michael Tewes, Frank D. Yturria Endowed Chair in Wild Cat Studies and Regents Professor)
The Denver Zoo (Collaborator/End-User, POC: Nanette Bragin, GIS Conservation Biologist)
South Texas Refuge Complex (Collaborator/End-User, POC: Mitch Sternberg, Zone Biologist-South Texas Gulf Coast)
Texas Department of Transportation (Collaborator/End-User, POC: Dr. John Young, Jr., Environmental Specialist)
Secretaria de Medio Ambiente y Recusos Naturales (SEMARNAT) (Collaborator/Boundary Organization/End-User, POC: Dr. Arturo Caso, Area Director)

The Pittsburgh Zoo and PPG Aquarium have shown an interest in ocelot recovery. Contact was initiated when Leigh Sinclair (DEVELOP Center Lead) and Amberle Keith (DEVELOP Assistant Center Lead and Young Professional) asked Ken Kaemmerer (Ocelot SSP) to be a partner for this project. Mr. Kaemmerer suggested multiple other partners, Michael Tewes (Texas A&M), Nanette Bragin (The Denver Zoo), Dr. Josh Gaspard (The Pittsburgh Zoo), Mitch Sternberg (South Texas Refuge Complex), Dr. John Young (Texas Department of Transportation), and Dr. Arturo Caso (SEMARNAT), and suggested a teleconference meeting to discuss the project further. At the teleconference meeting, a conversation was started about the use of satellite imagery for monitoring the habitat of the ocelot. Incorporating the use of NASA's Earth observations for ocelot habitat monitoring will help better understand where to manage the habitat loss. Also, utilizing NASA's Earth observations in ocelot habitat monitoring will provide a more spatially complete picture of the ocelot's habitat for enhanced ocelot habitat management decision-making.

Letters of Support:

1. Pittsburgh Zoo & PPG Aquarium (Collaborator/End-User, POC: Kenneth R. Kaemmerer, Ocelot SSP Chair and USFWS Ocelot Recovery Team)
2. Texas Department of Transportation (Collaborator/End-User, POC: Carlos Swonke, Director of Environmental Affairs Division)
3. Cincinnati Zoo and Botanical Gardens (Collaborator, POC: Shasta R. Bray, Ocelot Species Survival Plan Education Advisor and Interpretive Media Manager)

Decision Making Process:

Currently, remote sensing is not being utilized to monitor the decrease of the ocelot habitat. The efforts of this project in using Landsat and MODIS, aboard the Terra and Aqua satellites, will provide documentation of locations of good habitat left for the ocelot. Using the results of this project, the partners will be able to ground-truth the maps and then extent the methodology to Central America. This will help the project partners to better approximate ocelot population densities and the current amount of remaining suitable habitat. With this knowledge, it will provide support for prioritizing conservation efforts in prioritizing research.

The Texas Department of Transportation has expressed that the results of this project will assist with the design, construction, and placement of wildlife crossing structures by identifying where ocelots are more prevalent and more likely to cross roads for access to food, water, and shelter.

Earth Observations:

Platform	Sensor	Geophysical Parameter
Landsat 2,3,4,5,7,8	MSS, TM, ETM+, OLI	Spectral vegetation indices, land cover classifications, and land cover change
Terra and Aqua	MODIS	Spectral vegetation indices

NASA Earth Observations to be Highlighted:

The preferred habitats for the ocelot are semi-arid deserts in south Texas and the leafy jungle canopies in Mexico and Central America. This project will calculate vegetation indices, land cover classifications of these environments to show the loss of the ocelot habitat by highlighting the spectral, temporal, and spatial resolution capabilities of the Landsat series, which includes several sensors: the Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+), and Operational Land Imager (OLI). Using the MODIS sensor, onboard Terra and Aqua, vegetation indices will be created to capture the temporal resolution of the study area in the event of high cloud cover in the Landsat images.

Ancillary Datasets:

Ocelot habitat data, International Union for Conservation of Nature (ICUN), to determine the current locations of the ocelot habitat
Human population data, NASA's Socioeconomic Data and Applications Center (SEDAC), proximity to forested areas, grasslands, or ideal habitat of the ocelot
Current ocelot habitat data, Texas A&M University, to determine the current locations in South Texas and Arizona
Texas road GIS data, Texas Transportation Department, to determine where the locations of roads

Models

- Irdisi Land Change Modeler (POC: Sam Weber, former DEVELOPer, Team Lead of Myanmar Ecological Forecasting)
- Princeton University Maximum Entropy Distribution Model (Maxent) (POC: Jeffry Ely, NASA DEVELOP, Team Lead of Great Basin Climate)
- Spatial Data Modeler (POC: Gary Raines, Author of the python script)
- PatchMorph Patch Delineation Algorithm Tool (POC: Evan Girvetz, Postdoctoral Research Associate, University of Washington)

Decision Support Tools & Analyses:

Proposed End Products	Decision Impacting	Current Partner Tool/Method
Habitat Percent Cover Map	Prioritization of control and management	Aerial imagery and field surveys
Habitat Probability Map	Prioritization of control and management	N/A
Proximity Risk Map	Focus efforts for wildlife crossing structures	N/A

Habitat Percent Cover Map – This map will be derived by first identifying suitable ocelot habitat by creating land cover classifications to identify scrublands, jungle, agricultural, and urbanized areas. Using the classifications and human population data, the Irdisi Land Change Modeler to identify how land use has changed over time. Participants will assess the current percent cover of ocelot habitat.

Habitat Probability Map – This map will be created by combining the results of the Habitat Percent Cover Map and ground data in Maxent. This will identify areas that are more likely to be ocelot habitat.

Proximity Risk Map – This map will use the identified suitable ocelot habitat and identify areas that in proximity of roads. This will be assessed by using fuzzy logic and buffer tools in ArcGIS and rank areas from highest to lowest priority. The results of this map will identify areas where efforts should be focused to ground truth the products. This will then identify where wildlife crossings should be constructed.

Project Details:
National Application Area Addressed: Ecological Forecasting
Source of Project Idea: The DEVELOP Marshall team conducting research regarding endangered cat species and found conservation efforts focus on larger species such as jaguars or leopards, while smaller animals such as ocelots are overlooked. Since the ocelot habitat range is so extensive, the use of satellite imagery would greatly benefit project partners with cost and time management and communication with the potential partners began.

Advisor: Dr. Jeffrey Luvall (NASA at NSSTC)
# of Participants Requested: 3-4

Project Timeline: 2 Term: 2015 Summer-2015 Fall
Study Location: United States: Southeast Texas and Arizona
Period being Studied: January 1980 to December 2014

Previous Related DEVELOP Work:
Costa Rica Ecological Forecasting: Utilizing NASA Earth Observations to prioritize reforestation efforts in the Pájaro Campana Biological Corridor in Costa Rica - Fall 2013 (UGA)

Colombia Ecological Forecasting II: Utilizing NASA Earth Observations to Enhance the Conservation Efforts of Colombia's Most Endangered Primate, the Cotton-top Tamatin (Saguinus Oedipus) - Fall 2014 (UGA)

Myanmar Ecological Forecasting: Utilizing NASA Earth Observations to Monitor, Map and Analyze Mangrove Forests in Myanmar for Enhanced Conservation - Fall 2013 (Goddard)

Notes: This approach will take advantage of the Ocelots habitat characteristics. The ocelot's habitat usually consists of tall and thick vegetation such as forests or grassland.

Methodology and statistics can be found in the following articles:

Carlos A. López González, David E. Brown and Juan P. Gallo-Reynoso (2003). The ocelot Leopardus pardalis in north-western Mexico: ecology, distribution and conservation status. Oryx, 37, pp 358-364. doi:10.1017/S0030605303000620.

Di Bitetti, M. S., Paviolo, A. and De Angelo, C. (2006), Density, habitat use and activity patterns of ocelots (Leopardus pardalis) in the Atlantic Forest of Misiones, Argentina. Journal of Zoology, 270: 153–163. doi: 10.1111/j.1469-7998.2006.00102.

US Fish and Wildlife Service: http://www.fws.gov/endangered/esa-library/pdf/ocelot.pdf

5. Mississippi Ecological Forecasting

Using NASA Earth Observations to Locate Potential Habitat for the Dusky Gopher Frog

Objective:
This project will use NASA Earth observation data to locate potential breeding sites suitable for the endangered dusky gopher frog (*Lithobates sevosus*), a species currently only found in two small ponds within the DeSoto National Forest of Harrison County, Mississippi.

Community Concern:
The dusky gopher frog (DGF), *Lithobates sevosus*, is the most endangered species of frog in North America and is listed as one of the top 100 endangered species in the world. Currently, this species is found to inhabit and breed in only two, genetically isolated ponds in Harrison County, Mississippi. This small, wild population of less than one hundred is threatened by high risk of inbreeding depression due to genetic isolation, loss of habitat due to land development, wildfire suppression, and runoff from surrounding roadways. Diseases known to frogs, such as chytrid fungus, are also known to cause mortality in the DGF. Should DGF experience an outbreak of chytrid fungus, it has the potential to drive the species to extinction. Historically, these frogs inhabited the long leaf pine ecosystem and utilized burrows from the gopher tortoise (*Gopherus polyphemus),* which is also endangered. The reduction of long leaf pine forests, coupled with the highly specific habitat requirements of *Lithobates sevosus*, makes it especially challenging to

federal land wildlife managers to maintain existing populations and increase the number of viable populations through reintroduction and/or establishment of new populations.

End-Users/Partners/Boundary Organizations:
The Nature Conservancy (Collaborator/End-User, POC: Jim Lee, Biologist)
USDA Forest Service: DeSoto Ranger District (Boundary Organization, POC: Ed Moody, Wildlife Biologist)
US Fish and Wildlife Service (Collaborator/End-User, POC: Linda LaClaire, Wildlife Biologist)
US Army Corps of Engineers (Boundary Organization, POC: Danny Hartley, Wildlife Biologist)

On September 10, 2014, the USFWS released a draft recovery plan for *Rena sevosa* to the public. In this recovery plan, goals for the joint recovery effort were outlined for agencies and organizations listed above. These goals included creating a GIS database for the species and using remote sensing to locate preexisting and potential gopher frog ponds, which has not been previously done by these organizations. It is anticipated that project results and methodologies will be handed off in person during SSC Summer 2015 close-out or at TNC or USFS facilities on the Mississippi Gulf Coast. Products and information provided by this project will augment current decision making practices regarding where relocation and reintroduction ponds for the dusky gopher frog should be established in order to aid in monitoring, protection, and restoration of this critically endangered species.

Decision Making Process:
On September 10, 2014, the US Fish and Wildlife Service released a draft recovery plan for *Lithobates sevosus* outlining proposed steps and goals to locate existing ponds, to stabilize existing populations and to establish new populations by introducing DGF into modified habitats. In this document, the USFWS specifically includes goals to incorporate GIS and remote sensing into the DGF recovery plan previously. This includes obtaining and housing GIS data relevant to DGF conservation, using remote sensing and GIS to locate potential populations and suitable habitat for reintroduction, and locating existing populations that were previously unknown. In the past, all restoration efforts have been limited to field surveys and manual efforts to locate potential DGF habitat.

Earth Observations:

Platform	Sensor	Geophysical Parameter
Landsat 8	Operational Land Manager (OLI)	Vegetation Indices (Normalized Difference Vegetation Index, Normalized Difference Moisture Index), Land Use Land Cover
Landsat 5	TM	Historical Imagery, Vegetation Indices (NDVI), LULC
Terra	ASTER	Vegetation Indices (NDVI), Water Quality Indices, 30m DEM
Space Shuttle	SRTM	Elevation data and DEMs

NASA Earth Observations to be Highlighted:
Landsat 8 OLI will be used to calculate vegetation indices and produce updated land cover classifications. Landsat 8 OLI's panchromatic band will be used to pan-sharpen images from 30 meter resolution to 15 meter resolution, which will provide for greater detection of potential ponds. 15 meter ASTER imagery is also available for coastal Mississippi and will be used to calculate vegetation indices and water quality indices for the study area. Using this information, partnering organizations will be able to identify and map areas with the ideal land cover, water quality, and elevation characteristics for DGF habitation. Earth observations will be utilized to look at the following parameters:

- Identification of small pond water bodies
- Canopy cover
- Proximity to roadways
- Proximity to developed land
- Proximity to other bodies of water
- Appropriate pond hydrology over the course of the year (DGFs need ephemeral wetland areas with surface water lasting at least 195 days during breeding season)
- Emergent and submerged vegetation

Ancillary Datasets:

- National Landcover Dataset – USGS
- Gap Analysis Program (GAP)/LANDFIRE Landcover Dataset - USGS
- National Elevation Dataset (NED) – USGS
- LiDAR Elevation Dataset – Bare Earth DEM - USDA National Resources Conservation Service (NRCS)
- Historical precipitation data – NOAA
- Existing locations and extent of DGF Ponds – TNC, USFS, USFWS
- Location of previously surveyed areas for DGF habitat - TNC, USFS, USFWS
- High Resolution Aerial and Satellite Data – NAIP, ISERV, and other high resolution satellite data (e.g., QuickBird) if/when available for developing and evaluating other remote sensing based products
- NOAA CSC - Coastal Change Analysis Program (CCAP) Regional Land Cover product, NED

Models:

IDRISI Land Change Modeler for ArcGIS – Clark Labs (POC: Christine Rains, JPL DEVELOP)

Decision Support & Analyses:

Proposed End Products	Decision Impacting	Current Partner Tool/Method
Updated Landcover Classifications	Identification, restoration, and management of DGF habitat	Field surveys
Vegetation Indices	Identification, restoration, and management of DGF habitat	Field surveys
Topographical Map	Identification, restoration, and management of DGF habitat	Field surveys
Current Extent of Suitable Habitat Maps	Identification, restoration, and management of DGF habitat	Field surveys
Suitable Habitat Forecast	Identification, restoration, and management of DGF habitat	Field surveys

Updated Landcover Classifications – Landcover classifications will provide end-users with the most current land cover information and extent of cover types. LULC products can also be used by partners to plan monitoring and restoration activities.

Vegetation Indices – Spectral vegetation indices will be used to observe the current and past health of vegetation surrounding both current and potential gopher frog ponds. This will also be used to detect the presence or absence of emergent vegetation in ephemeral ponds. A time

series of vegetation indices will also be used in observing vegetation patterns of potential habitat. These products will be produced using Landsat 5 and 8 data as well as ASTER imagery.

Topographical Map – Topographical maps will provide end-users with a clearer understanding of existing topography at current and potential sites in order to best determine if and how sites need to be hydrologically altered in order to best suit DGF habitat specifications. These products will be provided through the use and refinement of existing ASTER DEMs and SRTM data.

Current extent of suitable DGF habitat across all DGF requirements – Geospatial mapping products depicting the current extent of existing *Lithobates sevosus* ponds will be created by combining the above end products with existing infrastructure data in order to highlight areas currently suitable for DGF habitation

Suitable Habitat Forecasts – The final and most valuable end products will be maps highlighting of the location of potential sites for reintroduction. This will be done by combining all of the above end products, using Landsat and ASTER imagery along with current habitat extent and existing infrastructure data, in order to highlight areas with the highest potential for successful DGF reintroduction and habitation.

Project Details:
National Application Area Addressed: Ecological Forecasting
Source of Project Idea: This project idea was suggested by participant and Assistant Center Lead Shelby Barrett based on knowledge gained from university coursework and related field trips that stressed long leaf pine ecosystem restoration and management of endangered species therein.

Advisors: Joseph Spruce (Senior Scientist and Lead Science Advisor at NASA SSC), James "Doc" Smoot (Senior Scientist and Assistant Science Advisor at NASA SSC), Dr. Kenton Ross (NASA DEVELOP National Science Advisor, LaRC)
# of Participants Requested: 5

Project Timeline: 1 term: 2015 Summer
Study Location: Southern Mississippi and St. Tammany Parish, LA
Period Being Studied: 2005-Present

Previous Related DEVELOP Work:
Mississippi Water Resources and Ecological Forecasting: *Utilizing NASA Earth Observations to Assist the Audubon Mississippi Coastal Bird Stewardship Program with Habitat Monitoring and Restoration Planning Activities* - Fall 2014 (start) and Spring 2015 (completion) (SSC)

Notes: *Lithobates sevosus* has extremely specific habitat requirements. DGF will only inhabit and breed in ephemeral wetland ponds that are geographically isolated from other water bodies, making rainfall the only source of water for these ponds. These need to be located on the topographic high of low lying areas. Ponds must also be hard bottomed, drain almost completely during the non-breeding season, have emergent and submergent vegetation present for egg attachment, and have open canopy cover (which is extremely important for tadpole development). The establishment of roadways or fragmenting land upland of these ponds is extremely detrimental to the delicate hydrographic period of these ponds. The majority of these qualifications can be observed by NASA Earth observation data at 15 meter resolution.

6. Ocmulgee Ecological Forecasting

Utilizing NASA's Earth Observations for Forecasting Land Use Change and Wildlife Disturbances along the Ocmulgee River Corridor

Objective:

The goal of this project is to utilize the time series produced in Term 1 to analyze the effects of changing conditions on the wildlife and fisheries in the Ocmulgee River corridor with a focus on endangered native species. This will provide the partners with information regarding threats to habitat and allow for ecological forecasting. Additionally, the team will explore the use of close-range unmanned aerial systems (UAS) coupled with NASA Earth observations for wildlife management.

Community Concern:

The Ocmulgee River corridor has exceptional conservation importance but is under increasing pressure from urban and suburban sprawl and the subdivision of large forested tracts. The corridor contains extensive bottomland hardwood swamps and other natural communities that support important plant and animal populations including Shortnose sturgeon and Atlantic sturgeon (both federally endangered), Robust redhorse, American shad, Striped bass and the state endangered Altamaha shiner. It serves as an important flyway habitat to millions of migratory birds, is home to the Central Georgia Black bear and contains several archeological remnants of pre-European Native American villages. The Ocmulgee River corridor is also a tremendous recreational resource that provides hunting, fishing, boating, hiking, and wildlife viewing opportunities, and is described as a high-priority landscape feature in Georgia's 2005 Wildlife Action Plan. It was also identified in 2006 as one of six Georgia Department of Natural Resources (GA DNR) land priority conservation areas.

End-Users/Partners/Boundary Organizations:

Georgia Department of Natural Resources (Partner/End-User, POC: Dan Forster, Director of Wildlife Resources Division; Thomas Litts, Special Project Operations Manager)
National Parks Conservation Association (Potential End-User, POC: Dr. Chris Watson, Senior Program Manager)

Contact with Thomas Litts at the Georgia Department of Natural Resources (GA DNR) Wildlife Resources Division has been made and project ideas have been discussed between Mr. Litts, Dr. Marguerite Madden (Science Advisor), Peter Hawman (DEVELOP Young Professional), and Caren Remillard (DEVELOP UGA Center Lead). The GA DNR anticipates that the project will result in tools that could be used to assess threats, to identify opportunities (e.g. easement, land acquisition), to communicate with conservation partners and the public, and to target best-management practice efforts. The GA DNR is a local partner and the UGA node will deliver the end-products in person and provide methodologies and tutorials of the decision support tools. The GA DNR will participate actively in the project and provide input or direction as needed.

Letters of Support:

Georgia Department of Natural Resources, Wildlife Resources Division; Dan Forster

Decision Making Process:

The Georgia Department of Natural Resources (GA DNR), Wildlife Resources Division (WRD) is charged with conserving, enhancing and promoting Georgia's wildlife resources, including game and nongame animals, fish, and protected plants. It is comprised of three sections: Game Management, Fisheries Management, and Nongame Conservation. The GA DNR uses numerous decision and management tools to conserve state-owned and -operated lands. These range from statistical and spatial analysis to fish stocking and prescribed burns. GA DNR currently uses

remotely sensed data to support management decisions, including National Agriculture Imagery Program imagery, LiDAR, side imaging sonar, digital elevation models, and products derived from satellite sensors. The GA DNR has personnel trained in GIS and remote sensing and will be able to take ownership and utilize the tools and products resulting from this DEVELOP project.

Earth Observations:

Platform	Sensor	Geophysical Parameter
Landsat 8	OLI	Land use
Terra	ASTER	Land use and DEM

NASA Earth Observations to be Highlighted:
The Operational Land Imager (OLI) on Landsat 8 is a push broom scanner designed to collect electromagnetic radiation reflected from Earth's surface across nine broad spectral bands. This new sensor and up-to-date imagery provide the most relevant and useful data to assess land use/land cover. The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) aboard Terra provides higher resolution imagery as well as digital elevation models.

Ancillary Datasets:

- 2012 Side Scan Sound Navigation And Ranging (SONAR) image data and Ocmulgee River substrate layers, GA DNR
- Index of Biotic Integrity fish sample data, GA DNR
- Long term sport fish monitoring data, GA DNR
- National Pollutant Discharge Elimination System (NPDES), 303d, Soils, geology and other environmental layers, GA DNR
- Rare plant / animal / fish survey data, GA DNR
- Parcel data, GA DNR
- National Land Cover Data set (NLCD), Multi-Resolution Land Characteristics Consortium (MRLC)
- UAS data, DJI Phantom 2 Vision +

Models:
A logistic regression model will be used to measure the relationship between environmental factors and fish diversity and water quality. The UGA science advisors have experience with this type of statistical modelling and will assist participants.

Decision Support & Analyses:

Proposed End Products	Decision Impacting	Current Partner Tool/Method
Land-use Forecast	Predict future land use change for management purposes	None
Threat and Opportunity Assessment	Quantitative results can be used to communicate and enhance management and conservation decisions for fisheries and wildlife	None

Land Use Forecast for Ocmulgee River Corridor – Using NLCD data sets for the years 2001, 2006, and 2011 and current Landsat 8 OLI imagery, the team will use their assessment of land use change trends to forecast future development impacting the Ocmulgee River and the surrounding ecosystems.

Threat and Opportunity Assessment – Using the time series analysis developed during the first term in conjunction with ancillary data listed above, the team will conduct statistical analyses

examining the relationship between development and natural resources (e.g. fish presence/absence/diversity) to complete a threat and opportunity assessment. Project partners can use these results to support their decisions regarding corridor management.

Project Details:
National Application Areas Addressed: Ecological Forecasting, Water Resources
Source of Project Idea: Dr. Marguerite Madden and Thomas Litts have been working together for 25 years and are interested in collaborating to use NASA imagery for exploring and predicting land-use change around the Ocmulgee River.

Advisors: Dr. Marguerite Madden (University of Georgia, Center for Geospatial Research), Dr. Thomas Jordan (University of Georgia, Center for Geospatial Research)
# of Participants Requested: 4-5

Project Timeline: 2 Terms: Spring 2015 to Summer 2015
Study Location: Ocmulgee River, Central Georgia
Period being Studied: 2001 to present

Previous Related DEVELOP Work:
Ocmulgee River Ecological Forecasting and Water Resources: Utilizing NASA's Earth observations for Forecasting Land Use Change and Wildlife Disturbances Along the Ocmulgee River Corridor

Multi-Term Objectives:
- **Term 1**– During term 1, the team utilized NLCD data sets for the years 2001, 2006, and 2011 and Landsat 8 imagery to create time series analysis of land use change affecting the Ocmulgee River corridor. Additionally the team used the most current Landsat 8 imagery available to assess the current land use in the study area.
- **Term 2 (proposed)** – During the second term, the team will use the land use classification results along with ancillary data provided by the GA DNR to assess the threat devlopment has on the resources found within and along the Ocmulgee River corridor. The team will use their assessment of land use change trends to forecast development impacting the Ocmulgee River and the surrounding ecosystems with a focus on available habitat for keystone species such as the Black bear and Atlantic sturgeon.

Note: This is a continuation of UGA's first collaborative DEVELOP project with the Georgia Department of Natural Resources.

7. Southeast US Ecological Forecasting

Utilizing NASA Earth Observations and Proximal Remote Sensing for Mapping the Spatio-temporal Distribution of *Hydrilla*

Objective:
The objective of this project is to develop a multi-platform approach for mapping the spatial and temporal distribution patterns of *Hydrilla sp.* sp. in several water bodies in Georgia and Florida.

Community Concern:
Hydrilla sp. sp. is an invasive aquatic plant that can negatively impact native vegetation and water quality. It outcompetes native plants by growing rapidly, forming a surface canopy that blocks the light passing though the water column, intensifies stratification and creates anoxic conditions in deeper areas. *Hydrilla sp.* has become one of the most serious aquatic weed

problems for the southeastern United States. It affects the food chain, as aquatic wildlife can die from consuming *Hydrilla sp.* with associated toxic epiphytic cyanobacteria. *Hydrilla sp.* is also a concern for the recreation industry, clogging boat motors, and becoming a swimming hazard. It can be economically costly as it obstructs water withdrawal for drinking, irrigation or power generation.

Located in the southwest corner of Georgia along its border with Florida, Lake Seminole is a United States Army Corps of Engineers (USACE) reservoir where there have been attempts to control *Hydrilla sp.* for almost 50 years using a combination of chemical, physical and biological controls. *Hydrilla sp.* in Lake Seminole has interfered with navigation, degraded water quality and fish and wildlife habitat, diminished recreation area use, increased mosquito populations, blocked hydropower intakes, and decreased adjacent property values. The USACE struggles to produce rapid accurate estimates of invasive plant density to determine which techniques provide the most cost-effective control throughout this large reservoir (37,500 acres) with extensive shoreline (570 km).

In 2013, Georgia Power experienced a rapid *Hydrilla sp.* invasion throughout two large reservoirs on the Chattahoochee River: Lake Harding (5850 acres) and Lake Oliver (2150 acres). During the fall of 2014, Georgia Power discovered *Hydrilla sp.* expanding into the next reservoir down in the series, Goat Rock Reservoir. They have received countless complaints from their stakeholder user groups including dock owners who are overrun with *Hydrilla sp.* and fisherman who can't motor through the thick mats. Georgia Power also requires a comprehensive assessment of *Hydrilla sp.* expansion to optimize their chemical control efforts. The production of accurate timely biomass maps will allow for adaptive plant management.

End-Users/Partners/Boundary Organizations:

Henry County Water Authority (End-user/Partner, POC: Ken Presley, Assistant Reservoir Manager)
J.W. Jones Ecological Research Center (Partner, POC: Dr. Stephen W. Golladay, Associate Scientist)
Georgia Power (End-user/Partner, POC: Anthony Dodd, Environmental Specialist)

DEVELOP University of Georgia Science Advisors have been assisting the Henry County Water Authority since 2010 when a *Hydrilla sp.* infestation was discovered in two of their newly constructed drinking water reservoirs. This *Hydrilla sp.* is creating recreation concerns for fisherman and waterfowl hunters and clogging their intake pipes. Bird deaths from Avian Vacuolar Myelinopathy, an emerging wildlife neurological disease linked to *Hydrilla sp.* have been documented at both reservoirs. Henry County needs a rapid, accurate assessment of the total acreage of *Hydrilla sp.* for effective management in order to stock sterile Grass Carp at the appropriate density for controlling the invasive vegetation without negatively affecting the fishery.

Contact has been made with all of the listed partners. They welcome the use of remote sensing tools to help understand the seasonal development and annual variation in invasive species distributions in lake environments. Partners are interested in enhancing water management plans as well as assessing future biological invasions. They have offered to provide years of field verified vegetation maps, a 10-year water quality dataset, and access and logistical support for additional field validation the DEVELOP team may like to complete over the course of the project.

Letters of Support:

J.W. Jones Ecological Research Center (Dr. Stephen W. Golladay, Associate Scientist)

Decision Making Process:
Currently, chemicals are used to manage *Hydrilla sp.*, including copper, diguat, endothall, and fluridone. Applying these chemicals can have adverse effects on the lake ecosystem. A lower impact strategy has been to introduce triploid (sterile) Grass Carp *(Ctenopharyngodon idella),* a species of fish which consumes aquatic plant material including *Hydrilla sp.*. Because triploid Grass Carp are sterile, their populations can be controlled after introduction to an ecosystem. Partners currently use traditional monitoring practices involving visual analysis, rake collection and sonar analysis.

In order for current control methods to be effectively implemented, these organizations need a rapid accurate assessment of *Hydrilla sp.* biomass over the growing season. Additionally, they need to have time-series evaluations of the efficacy of their chemical and biological control actions to optimize and adaptively manage this invasive species.

Earth Observations:

Platform	Sensor	Geophysical Parameter
Landsat 8	OLI	*Hydrilla sp.* distribution and vegetation indices

NASA Earth Observations to be Highlighted:
The team will use NASA's Landsat 8 Operational Land Imager (OLI) datasets to estimate *Hydrilla sp.* density and distribution in the three select sites. Landsat 8, being a relatively new sensor, has not been used to monitor *Hydrilla sp.* in Georgia-Florida waters. The team will apply field-based and unmanned aerial system (UAS)-based models to Landsat 8 OLI data in order to map the spatio-temporal distribution of *Hydrilla sp*. The proposed work is innovative, because it will allow the use of NASA Landsat 8 data to study the spread of the aquatic invasive plants in GA and FL inland waters. The results will be an efficient and non-destructive mapping protocol in the form of a detection tool for monitoring the *Hydrilla sp.* distribution to be used in water quality restoration decision making.

Ancillary Datasets:
Field data will be used for model calibration, tuning, and validation and it is a crucial part of the project.

- Unmanned aerial system, DJI Phantom 2 Vision +
- Hyperspectral digital camera Basler acA1300, University of Georgia
- Ocean optics non-imaging hyperspectral radiometer, University of Georgia
- *Hydrilla sp.* locations, density per area, and plant height data

Models:

- Radiative Transfer Models (Benthic Mapping) (POC: Deepak Mishra, UGA)
- Green NDVI (POC: Deepak Mishra, UGA)

Decision Support Tools & Analyses:

Proposed End Products	Decision Impacting	Current Partner Tool/Method
Landsat 8 Benthic Model for *Hydrilla sp.* Mapping	Detecting and predicting *Hydrilla sp.* to support pre-emptive, planning efforts	Field sampling
Hydrilla sp. Distribution Maps	Where lake managers target mitigation efforts	Field sampling

Landsat 8 Benthic Model for Hydrilla sp. Mapping – The data from different platforms will be compared to develop a scaled-up benthic mapping model using spectral matching techniques. The Landsat 8 based benthic model will also be used to correct the residual

atmospheric noise in the data after the FLAASH correction. A benthic mapping radiative transfer model developed by Mishra et al. (2005 and 2006) will be used to extract the bottom reflectance (i.e., *Hydrilla sp.* reflectance) from Landsat 8 data resulting in a density/detection tool for *Hydrilla sp.* in inland waters. This tool will help lake managers to understand the factors that support the development of *Hydrilla sp.*

Hydrilla sp. Distribution Maps – Landsat 8 based map products will be generated detailing density and spatio-temporal variations of *Hydrilla sp*. Maps will be analyzed to study the phenology involving *Hydrilla sp.* initiation, growth, and senescence. These maps will inform manager's decisions on where to target their control methods in Georgia and Florida waters.

Project Details:
National Application Areas Addressed: Ecological Forecasting, Water Resources
Source of Project Idea: The project idea originated from previous partner interaction with Georgia Power. Anthony Dodd, Environmental Specialist from Georgia Power, expressed interest beginning a DEVELOP project focusing on the spread of *Hydrilla sp.* in Georgia lakes.

Advisors: Dr. Deepak Mishra (Department of Geography, University of Georgia-Athens), Dr. Susan Wilde (Warnell School of Forestry and Natural Resources, University of Georgia-Athens)
# of Participants Requested: 5

Project Timeline: 3 terms: Summer 2015 to Fall 2015
Study Location: Georgia and Florida
Period being Studied: 2014 (Terms 1 and 2) and 2000 to 2014 (Term 3)

Previous Related DEVELOP Work:
Georgia Water Resources: Developing a Cyanobacteria Detection Tool for Georgia Inland Waters Using NASA Landsat 8 OLI Data for Water Quality Protection and Restoration - Fall 2014 (UGA)

Multi-Term Objectives:
- **Term 1 (Proposed Term)** – In situ sampling and proximal remote sensing sata collection. Atmospheric correction of Landsat 8 data and reflectance extraction. Development and calibration of Landsat 8-based *Hydrilla sp.* benthic model
- **Term 2**– Additional field data collection and Landsat 8 based benthic model validation. Application of the model to generate *Hydrilla sp.* distribution maps for the study sites. Model tuning if necessary.
- **Term 3** – Model operation - Apply model to a wider study area over multiple years and analyze the spatio-temporal spread of the aquatic invasive plant and its linkage to climate change throughout the southeastern United States. Coordinate with project partners to understand the biophysical forcing controlling the *Hydrilla sp.* Distribution. Outreach and product dissemination.