NASA DEVELOP National Program
Summer 2016 Project Proposal

NASA Ames Research Center
Elkhorn Slough Ecological Forecasting
Assessing the Impacts of Changing Climatic Variables and Nutrient Levels in California's Elkhorn Slough

Project Overview

Objective: To assess the effects of nutrient loading in the Elkhorn Slough and determine eutrophication sources using hydrological modeling

Community Concern: The Elkhorn Slough, located in the center of California's Monterey Bay coastline, is a region of great biodiversity and essential ecosystem services. Home to over 135 aquatic birds, 550 marine invertebrates, and 102 fish species, the slough provides habitat to several endangered species, such as the steelhead trout. It also harbors sea lions, seals, and sea otters, and serves as a destination for over 200 migrating bird species. Several important ecosystem services that the slough provides include sequestering carbon, filtering water between freshwater streams and the Pacific Ocean, and reducing the impacts of flooding. However, the slough currently faces very high nitrate, phosphate, and turbidity levels in the southern estuary, along with low concentrations of dissolved oxygen in the Upper Elkhorn Slough, which are believed to be a direct result of nutrient influxes from surrounding agricultural plots. Such changes to water quality in the slough can lead to eutrophication, hypoxia, and the death of aquatic and terrestrial species. These observations, along with the threat of rising sea level and subsiding marshes, demonstrate the necessity to further analyze the effects of increasing nutrient loads, sea level heights, and sedimentation within the Elkhorn Slough and surrounding watershed.

National Application Area Addressed: Ecological Forecasting, Water Resources, Climate
Study Location: Elkhorn Slough, CA, and surrounding sub-basins (within 5-mile radius)
Study Period: March 1995 to March 2016 for time series analysis; Forecasting through 2017

Advisors: Sherry Palacios (Bay Area Environmental Research Institute), Juan Torres-Pérez (Bay Area Environmental Research Institute)

Source of Project Idea: A science advisor at the NASA Ames Research Center, Dr. Sherry Palacios, worked with the Elkhorn Slough National Estuarine Research Reserve (ESNERR) during her previous studies at Moss Landing Marine Laboratory. She provided the ARC DEVELOP team with contact information for Dr. Kerstin Wasson, ESNERR's Research Coordinator, and suggested collaborating on a project involving water quality, eelgrass, otter habitat, and eutrophication. Upon speaking with Dr. Kerstin Wasson and Charlie Endris, ESNERR's GIS Specialist, it became apparent that there was a need for further investigation of climatic variations within this region. It also became clear that these partners could benefit from a large-scale monitoring approach and historical analysis of the Elkhorn Slough using NASA Earth observations. Researchers at ESNERR are interested in exploring several topics, such as the effects of nutrient influx from the greater watershed on the slough, and how different levels of sea inundation would affect carbon sequestration loss and marsh vegetation health.

Partner Overview

Partner Organizations:

Organization	POC (Name, Position/Title)	Partner Type	Boundary Org?
Elkhorn Slough National Estuarine Research Reserve (ESNERR)	Dr. Kerstin Wasson, Research Coordinator; Charlie Endris, GIS Specialist; John Haskins, Water Quality Monitoring Specialist	End-User	Yes
Monterey Bay Aquarium Research Institute	Dr. Ken Johnson, Senior Scientist	Collaborator	No
USGS, Western Geographic Science Center	Dr. Kristin Byrd, Research Physical Scientist	Collaborator	No

End-User Overview

End-User's Current Decision Making Process:

Currently, ESNERR conducts estuarine research, and disseminates their results to local agencies that include California's Central Coast Regional Water Quality Control Board (RWQCB), the USDA National Resources Conservation Services (NRCS), and the Central Coast Region Resource Conservation District Boundaries (RCD). The RWQCB approves the Total Maximum Daily Loads (TMDLs), or allowable pollutants, within their jurisdiction (which includes the Elkhorn Slough and surrounding watershed), and they frequently cite ESNERR's research and data when creating these regulatory standards for this region. Understanding the historical perspective of nutrient loading and sedimentation in the Elkhorn Slough via NASA satellite imagery, which is currently not incorporated into ESNERR's monitoring methodologies, would influence the water quality standards set by the RWQCB. Additionally, the NRCS and the RCD, both of which work directly with farmers on regulation, incentive, and education initiatives, would greatly benefit from the outputs of the Soil and Water Assessment Tool (SWAT) model, as well as a time series created from Landsat imagery; this would provide a historical context for the nutrient loading in the Elkhorn Slough and surrounding watershed.

Furthermore, the Elkhorn Slough estuary is undergoing a Tidal Marsh Restoration Project, which involves adding sediment to a subsided marsh to increase resilience in the face of rising sea levels. This project is part of the 5-year Tidal Wetland Project that began in 2014, which seeks to: restore marsh through sediment addition (Tidal Marsh Restoration Project), conduct marsh sustainability research, restore tidally-restrictive habitats, assess eutrophication and nutrient-loading, and engage in collaborative goal-setting and implementation with the Tidal Wetland Group, ESNERR researchers, and RWQCB. None of these approaches uses satellite imagery to assess or model marsh health, and ESNERR would benefit from a larger-scale approach that incorporates Landsat imagery analysis into determining goals, risks, and suitability of marsh restoration.

End-User's NASA Earth Observations Capacity:

Elkhorn Slough National Estuarine Research Reserve (ESNERR)– Charlie Endris, ESNERR's GIS Specialist, worked with MODIS data several years ago during an oceanographic project, however he has never applied NASA Earth observations to marsh studies or restoration. Therefore, this project would build the capacity of ESNERR to supplement *in situ* marsh measurements with remotely-sensed measurements and modeled results.

Collaborator & Boundary Organization Overview

Collaborator Support:

Monterey Bay Aquarium Research Institute – Dr. Ken Johnson manages the Land-Ocean Biogeochemical Observatory (LOBO), which is an environmental sensor network that monitors

nitrogen, eutrophication, and hypoxia in the slough. He is willing to host telecons with the ARC DEVELOP team during the term, and respond via email as necessary.

USGS – Dr. Kristin Byrd has experience doing research in the slough and running the Marsh Equilibrium Model (MEM) in previous research studies. She will serve as an advisor for this model, and is willing to speak to the team as needed.

Boundary Organization Dissemination:
Elkhorn Slough National Estuarine Research Reserve (ESNERR) – Staff at ESNERR engage in science and conservation outreach through many different mechanisms. They produce Water Quality Report Cards that are disseminated online and at workshops, and these serve as user-friendly indexes to educate the public about the current state of the slough's water. ESNERR's Coastal Training Program provides tours and presentations to board members of the Central Coast Regional Water Quality Control Board (RWQCB) several times a year, and this group serves as a conduit between scientists and decision-makers. Finally, ESNERR hosts public workshops at the Moss Landing Marine Labs, and their most recent workshop was filled to capacity. ESNERR has requested that the ARC DEVELOP group present their findings and results to the RWQCB, NRCS, and RCD at the culmination of the project.

Project Communication & Transition Overview
In-Term Communication Plan:
The team will communicate with ESNERR at least three times throughout each term. The main POC for this communication will be Chippie Kislik, the current Center Lead, the Assistant Center Lead, Vickie Ly, as well as the Team Lead of each respective term.

Transition Approach:
Results and manuals produced from this project will be emailed to ESNERR at the end of each term, and presented orally on site. The team will disseminate the analyses to RWQCB, NRCS, and RCD for use in influencing agricultural regulations and TMDL recommendations, and ESNERR can utilize these results in their 5-year Tidal Wetland Project. Software release will not be required.

Letter of Support: Elkhorn Slough National Estuarine Research Reserve (ESNERR), Dr. Kerstin Wasson, Research Coordinator.

Earth Observations Overview

Earth Observations:

Platform & Sensor	Parameter(s)	Use
Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI	Floating Algal Index (FAI), Normalized Difference Turbidity Index (NDTI), Suspended Sediment Concentration (SSC)	(1995-2016): Compare chlorophyll a and turbidity readings from satellite imagery with *in situ* measurements in the slough. Act as a broader source of collection for slough dynamics. This will ultimately help the end-user assess water quality in Elkhorn Slough. Landsats 5, 7, and 8 data will also be useful in estimating the average suspended sediment, which is an input for MEM. This will help the end-users understand how sediments contribute to the health of the slough.
Aqua/Terra MODIS	Chlorophyll A (Chl), Remote Sensing	These parameters will be helpful when running the SWAT model and assessing

	Reflectance (Rrs), Sea Surface Temperature (SST), Photosynthetically Available Radiation (PAR), Colored Dissolved Organic Matter (CDOM)	agricultural variables that affect the water quality of the Elkhorn Slough and surrounding watershed.
AVIRIS	Floating Algal Index (FAI), Normalized Turbidity Index (NDTI)	Compare chlorophyll a and turbidity readings from airborne imagery with *in situ* measurements in the slough. Act as a broader source of collection for slough dynamics, but at better resolution than satellite imagery. This will ultimately help the end-user assess water quality in Elkhorn Slough.

Ancillary Datasets:

Elkhorn Slough – ammonia, ammonia (unionized), algal cover, chlorophyll a, nitrate, orthophosphates, turbidity, dissolved oxygen, pH, salinity, temperature – model inputs for SWAT and MEM

Monterey Bay Aquarium Research Institute – (LOBO) – nitrate, water depth, salinity, temperature, oxygen, pH, chlorophyll, colored dissolved organic matter, solar radiation, precipitation, wind speed, wind direction, evapotranspiration – model inputs for SWAT and MEM

NOAA Coastal Dataset – land cover dataset – model inputs for SWAT and MEM

NOAA Coastal Services Center – LiDAR elevation data – model inputs for SWAT and MEM

Models:

Soil and Water Assessment Tool (POC: Irma Caraballo-Alvarez, ARC DEVELOP team member)

Marsh Equilibrium Model (POC: Kristin Byrd, USGS)

TerrSet's Earth Trends Modeler (POC: James Toledano, Clark Labs/ Clark University)

TerrSet's Climate Change Adaptation Modeler (POC: James Toledano, Clark Labs/ Clark University)

Decision Support Tool & End-Product Overview

End Products:

End Products	Partner Use	Datasets & Analyses	Software Release Category
Time Series of Eutrophication events in Elkhorn Slough	This will help create a narrative about the seasonality and occurrences of high eutrophic periods in this region.	This time series (1995-2015) will be based off Landsat 5, 7, and 8 images of the slough, and compiled in TerrSet's Earth Trends Modeler.	1
SWAT Model Outputs	The SWAT Model will help end-users understand how the greater watershed is influencing eutrophication in the slough, and can assist	The SWAT Model will be run using *in situ* datasets provided by ESNERR and LOBO, as well as Landsat and MODIS product inputs.	1

	them in informing policy-makers about nutrient runoff levels.		
SWAT Manual	This manual will be helpful for the end-users because it will allow them to run the model using different or more updated parameters after the project has ended.	SWAT model inputs, outputs, and calibration will be documented.	1
Time Series and Analysis of Restored Marsh Scenarios and MEM outputs	Different scenarios (modeled after periods of high drought, periods of severe El Niño storms, and different rates of sea level rise and sediment concentrations) will allow the end-users to understand the potential effects of climatic variation and changes on the health of the slough. These outcomes will pertain to blue carbon (carbon sequestration potential of the ocean), and vegetation health within Elkhorn Slough.	This time series will be run based on *in situ* data provided by ESNERR and LOBO, and will be calibrated using the slough's soil accretion rates. The format of these products will be in graphs, Excel tables, and visualizations.	1
MEM Manual	This manual will be helpful for the end-users because it will allow them to run the model using different or more updated parameters after the project has ended.	MEM inputs, outputs, and calibration will be documented.	1

End-User Benefit:
ESNERR will be able to use the products listed above in their management decisions regarding how to best respond to subsiding land within the slough, rising sea levels, and increased nutrient loadings from nearby agricultural plots. This will help them implement specific mitigation techniques into their current 5-year Tidal Wetland Project, and continue to educate the public and the Regional Water Quality Control Board about water quality issues in the slough. Furthermore, data on nutrient loading in the greater surrounding watershed will help inform the RWQCB on their TMDL recommendations for the Central Coast region, and will assist the NRCS and RCD in creating agricultural regulations, incentives, and educational programs for farmers in the region. Incorporating satellite imagery into these analyses will provide a historical framework for informing these regulatory measures, and modeling different environmental scenarios will help the end-user understand the potential impacts of climatic and nutrient variation within the Elkhorn Slough and surrounding watershed.

Project Timeline & Previous Related Work

Project Timeline: 2 Terms: 2016 Summer (Start) to 2016 Fall (Completion)

Multi-Term Objectives:

- **Term 1 (Proposed Term):** 2016 Summer (ARC) – Elkhorn Slough Ecological Forecasting I

    - The goals for this first term are to analyze Landsat 5, 7 and 8 images of eutrophication hotspots of the slough during highly eutrophic time periods, and create a time series analysis of these events. Next, the team will acquire data for the Soil and Water Assessment Tool (SWAT) and run this to assess potential sources of eutrophication in the sub-basins surrounding the slough. The model will be calibrated using the slough's soil accretion rates and soil cores. The team will also produce and disseminate a SWAT manual for the end-users. Communication will occur via telecons about three times throughout the term, and products will be provided and presented to the partners at the end of the term. The summer term will set the stage for subsequent terms because data will be acquired and processed, with one aspect of the slough's water quality already analyzed.
- **Term 2:** 2016 Fall (ARC) – Elkhorn Slough Ecological Forecasting II
    - This second term will focus on running the Marsh Equilibrium Model (MEM). The team will analyze the effects of different sea level rise, weather, and sedimentation scenarios on marsh vegetation resilience and carbon sequestration capabilities. If there is time, the team can then assess the results of MEM and compare them to results of the same parameters run in a similar model: TerrSet's Climatic Change Adaptation Modeler. The team will continue to communicate with the end-users throughout the term and will hand off all end products via email and in-person at the end of the term. The team's results will be presented in a local workshop hosted by ESNRR at the culmination of the project.

Related DEVELOP Work:

Fall 2015 (JPL) – Louisiana Ecological Forecasting: Using UAVSAR, AVIRIS and AirSWOT to Examine Historical Trends and Model Sediment Transport within the Wax Lake Delta, Louisiana, to Inform Coastal Restoration Efforts

Summer 2015 (ARC) – Mexico Water Resources: Utilizing NASA Earth Observations to Detect Factors Contributing to Hypoxic Events in the Southern Gulf of Mexico

Spring 2011 (ARC) – California Ecological Forecasting: Hyperspectral Biofilm Classification Analysis for Carrying Capacity of Migratory Birds in the South Bay Salt Ponds

Project Needs/Requests

Participants Requested: 4

Software & Scripting:

TerrSet Earth Trends Modeler, Climate Change Adaptation Modeler, Habitat and Biodiversity Modeler – assess the seasonality of eutrophication, analyze the effects of sea level rise in the slough, and identify localized regions of habitat and biodiversity.

ENVI – Classification of Landsat images

ESRI ArcGIS – Classification of Landsat images

Notes & References:

Notes: The end-user has wanted to assess the surrounding watershed's impacts on eutrophication in Elkhorn Slough, as well as run the Marsh Equilibrium Model, for some time. For this reason, they have specifically requested that this project focus on these two items, as this research would greatly impact their decision-making processes related to the restoration goals of their current 5-year Tidal Wetland Project.

References:

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