**Coastal California Water Resources**

*Assessing Estuarine Ecosystems in California for Improved Wetland Monitoring and Management*

**Project Team**

***Project Team:***

Karina Alvarez (Project Lead)

Molly Bruce

Roger Ly

Sarah Payne

***Advisors & Mentors:***

Benjamin Holt (NASA Jet Propulsion Laboratory, California Institute of Technology)

Dr. Christine Lee (NASA Jet Propulsion Laboratory, California Institute of Technology)

Dr. Bruce Chapman (NASA Jet Propulsion Laboratory, California Institute of Technology)

***Team POC:*** Karina Alvarez, karina.alvarez@ssaihq.com

***Software Release POC:*** Sarah Payne, sarahallisonrose@gmail.com

***Partner POC:*** Kevin O’Connor, koconnor@mlml.calstate.edu

**Project Overview**

***Project Synopsis:***

The Marine Life Protection Act demands an improvement in data collection and monitoring of California’s estuaries. Partnering with the Ocean Protection Council (OPC), Central Coast Wetlands Group (CCWG), and the Southern California Coastal Water Research Project (SCCWRP), this project supplements ground-based data collection by creating a Google Earth Engine tool to visualize, characterize, and assess estuary processes using Landsat 8 OLI, Sentinel-2 MSI, and Sentinel-1 C-SAR data. By assessing estuary mouth state, inundation extent, and water quality metrics, this tool will enable partners to better understand and monitor estuarine dynamics.

***Abstract:***

Estuaries are vital ecosystems that serve important ecological functions. The Marine Life Protection Act aims to protect these ecosystems by establishing a network of marine protected areas (MPAs), in part by requiring regulatory agencies to monitor estuary extent and health. However, California has 23 estuarine MPAs (EMPAs) and approximately 440,000 total acres of estuarine habitat, making ground-based data collection time and resource intensive. This project used remotely sensed data to examine the health of California EMPAs in an effort to supplement ground-based field measurements. Using Landsat 8 Operational Land Imager (OLI), Sentinel-2  MultiSpectral Instrument (MSI), and Sentinel-1 C-band Synthetic Aperture Radar (C-SAR), this project assessed mouth state, inundation extent, turbidity, Chlorophyll-a, and colored dissolved organic matter (CDOM) for estuaries observable with these sensors. Determining the Normalized Water Difference Index (NDWI) from Sentinel-2 MSI data captured estuary mouth state and inundation extent. Meanwhile, Landsat 8 OLI and Sentinel-2 MSI indicated a capacity to capture differences in water quality metrics coinciding with changes to estuary mouth state using algorithms applied in Google Earth Engine (GEE). The GEE California Estuary Assessment tools will allow project partners to better monitor and understand estuarine dynamics and health.

***Key Terms:***

Marine Protected Areas, Google Earth Engine, turbidity, pixel connectivity, breach

***National Application Area Addressed:*** Water Resources

***Study Location:*** Estuarine Marine Protected Areas, CA

***Study Period:*** January 2018 – present

***Community Concerns:***

* Estuaries are plentiful along the California coast and are vital ecosystems serving a multitude of important functions such as nurseries for fish and invertebrate species, habitat for endangered animals, and natural filtration of pollutants to the ocean.
* High levels of anthropogenic activity impacting the California coast—anthropogenic activity that causes stressors including pollution, wildfires, and urbanization of the coastal zone—have resulted in varied and often extreme levels of disturbance that have changed the natural timing, magnitude, and/or duration of important estuarine processes.
* One such process is breaching: when the barrier at the mouth of the estuary–– the sand bar that separates the inland, freshwater source from the ocean––is broken. Another such process is reformation of this barrier. Both of these processes change the state of the estuary mouth. Breaching and reformation occur at variable frequency and result in highly variable water quality conditions. Monitoring with a high temporal resolution would provide a more nuanced understanding of these highly dynamic systems.
* The California legislature passed the Marine Life Protection Act to protect these systems, in part by requiring statewide network monitoring of Marine Protected Areas (MPAs). This monitoring is funded by the Ocean Protection Council, an agency that serves as the California Governor’s advisor on coasts and oceans.
* Using field-based monitoring of estuary extent and health is costly and time-consuming, thereby limiting agencies’ capacity to gather data and curtailing decision-makers’ ability to incorporate reliable and recent data for wetland resources management. Remote sensing has the capacity to expand data collection capabilities at regular time intervals along the entire California coastline without imposing prohibitive costs on these agencies.
* Unlike other ecosystems classified as MPAs in California, there is a scarcity of data and monitoring of estuary ecosystem functioning.

***Project Objectives:***

* Improve data collection of EMPAs throughout California by incorporating remote sensing
* Create an estuary assessment tool in GEE for California (California Estuary Assessment CEA tools)
* Identify mouth state and inundation extent of estuaries
* Assess water quality metrics including turbidity, Chlorophyll-a, and colored dissolved organic matter (CDOM)

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Ocean Protection Council** | Michael Esgro, Marine Ecosystems Program Manager | End User | Yes |
| **Southern California Coastal Water Resource Project** | Dr. Eric Stein, Biology Department Head; Kristine Taniguchi-Quan, Scientist, Biology Department | Collaborator | Yes |
| **Moss Landing Laboratories, Central Coast Wetlands Group** | Ross Clark, Director/Principal Investigator; Kevin O’Connor, Program Manager | Collaborator | Yes |
| **University of California Los Angeles, Institute of the Environment & Sustainability** | Dr. Kyle Cavanaugh, Vice Director of Marine Center | Collaborator | No |

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

The OPC is a decision-making agency that advises the California Governor on coasts and oceans. The OPC funds other agencies to conduct long-term MPA and estuary monitoring efforts and provides scientific and technological support for state-level regulatory agencies. Currently, the OPC does not use remote sensing for EMPA monitoring, and assessments are primarily made using *in situ* data collection. The foremost state law that guides the OPC’s monitoring and assessment is the 1999 MLPA. Under the MLPA, baseline and long-term monitoring are collaboratively undertaken by the OPC, California Department of Fish and Wildlife (CDFW), and the Fish and Game Commission. The OPC and CDFW’s MPA Monitoring Action Plan outlines actions to evaluate the statewide MPA network through a combination of private and public partnerships.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 8 OLI** | Reflectance values in visible light (RGB), near infrared (NIR), and shortwave infrared (SWIR) at 30 m. resolution at 16-day intervals. Contains panchromatic image at 15 m. resolution | Used to measure turbidity. Measurements will be used as estuary health parameters. |
| **Sentinel-2 MSI** | Reflectance values in visible light, red edge, NIR, and SWIR at 10-20 m. resolution at a varied temporal resolution of approximately 2-3 days. | Used to create water indices (NDWI and NDCI) that detect estuary mouth state and measure Chlorophyll-a, CDOM, and turbidity. Both indices will be used to assess estuary health. |
| **Sentinel-1 C-SAR** | Backscatter values, vertical transmit/vertical receive (VV), and vertical transmit/horizontal receive (VH) Polarization at the C-band frequency, 10 m. resolution at 12-day intervals. | Used to identify inundation. Inundation will be used as an estuary health parameter. |

***Ancillary Datasets:***

* United States Fish and Wildlife Service National Wetlands Inventory Wetlands – Used to compare satellite-based wetland assessments
* USGS 3D Elevation Project 1m DEMs – Used to determine areas of potential inundation
* NOAA Coastal National Elevation Database 1 m DEMs – Used to determine areas of potential inundation
* Moss Landing Marine Laboratories, Central Coast Wetlands Group water level data for various EMPAs – Used for preliminary validation of breach, inundation extent, and water quality results

***Software & Scripting:***

* Google Earth Engine API – Create tools for assessing estuary mouth state, inundation, and water quality parameters
* ESRI ArcMap 10.7.1 – Create EMPA shapefiles
* Optical Reef and Coastal Area Assessment (ORCAA) tool – Assess coastal water quality parameters
* Wetland Extent Tool (WET) – Assess wetland inundation

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Estuary Classification Datasets (raster)** | Sentinel-2 MSI | These layers will capture the estuary mouth state as open or closed, visualize inundation levels, and classify estuary features. | I |
| **Estuary Classification Time Series (csv/chart)** | Sentinel-2 MSI | Time series of estuary mouth state and inundation extent will provide insight into estuary state over time. | I |
| **Estuary Inundation Time Series (csv/chart)** | Sentinel-1 C-SAR | Time series of estuary inundation extent will provide insights into estuary state over time.  | I |
| **Estuary Health Assessment Datasets (raster)** | Landsat 8 OLI, Sentinel-2 MSI | These layers will be used by our partners to assist in the monitoring of EMPA health by examining turbidity, Chlorophyll-a, and CDOM. | I |
| **California Estuary Assessment (CEA) Tools** | Landsat 8 OLI, Sentinel-1 C-SAR, and Sentinel-2 MSI | This set of Google Earth Engine tools will provide a user-friendly interface to easily replicate our estuary classification and health assessment.  | IV |

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

The estuary monitoring products built in this term will be used to inform future conservation strategies in EMPAs. The OPC collects various metrics that assess water quality and invasive species and report these metrics to California state government agencies. However, there are no reliable alternatives to cost and time-intensive ground-based monitoring. The estuary assessment and monitoring products produced by the team will allow the OPC to reduce costs associated with field data collection through the incorporation of remotely sensed data. Additionally, these end products will help support existing monitoring programs by providing data that facilitate a more nuanced analysis of estuarine habitat dynamics while incorporating ground-based monitoring.

***Project Continuation Plan:***

This project spans two terms. The first term expects to hand off to the second term a set of functional Google Earth Engine scripts that evaluate measures of estuary health in coastal California through time-series analysis of estuary mouth state detection, inundation extent changes, and water quality metrics. The first term expects to hand off to the partners the products listed in the chart above. The first term will also provide the partners with a collection of rasters of select water indices and C-SAR imagery from the study period, representative snapshot maps of water quality metrics, and time series of all metrics for the length of the study period. There will be opportunities for the second term to improve upon the script, for instance by building out a user-friendly interface and incorporating ground-based measurements for validation.

**References**

*Marine Protected Area Monitoring Action Plan* (October 2018). California Department of Fish and Wildlife and California Ocean Protection Council, California, USA.

*Wetland Research and Assessments – Central Coast Wetlands Group*. (n.d.). Retrieved February 9, 2021, from <https://www.mlml.calstate.edu/ccwg/wetland-research/>