**NASA DEVELOP National Program**

**California – JPL**

*Project Summary – Summer 2018*

**Southern California Water Resources II**

*Predicting Grunion Migration Patterns and Spawning Areas in Response to Changes in California’s Oceans*

**VPS Title:** High Tides Bring the Silversides

**Project Team**

***Project Team*:**

Alexandra Jones (Project Lead), lexxii1456@gmail.com

Harrison Knapp

Annemarie Peacock

Lael Wakamatsu

***Advisors & Mentors*:**

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

***Past or Other Contributors*:**

Sol Kim

Ariana Nickmeyer

**Project Overview**

***Project Synopsis*:**

The California grunion (*Leuresthes tenuis*) is an endemic fish species found along the coast of California and Baja California. This study analyzed sea surface temperature and chlorophyll-a concentration measurements using NASA JPL Multi-scale Ultra-high Resolution (MUR) and Aqua Moderate Resolution Imaging Spectroradiometer (MODIS), and paired them with *in situ* data to examine spatio-temporal patterns of environmental conditions that influence grunion spawning runs. The results will support the Grunion Greeters Project to help enhance the understanding of grunion migration patterns, and will be shared with the California Department of Fish and Wildlife to support their efforts to conserve the grunion population and habitat.

***Abstract*:**

The California grunion (*Leuresthes tenuis*) is a species of fish endemic to the California coastline that plays an important role in the marine food chain as a consumer of zooplankton and a food source for larger marine creatures. Grunion spawning events, commonly referred to as “grunion runs,” occur when the tide is highest during nights surrounding a new or full moon, allowing the fish to “run” up the beach to deposit and fertilize their eggs before returning to sea. These runs happen most frequently during the summer months along beaches in Los Angeles, Orange, and San Diego counties. However, spawning events documented over the last three decades in the San Francisco Bay suggest a pattern of northern migration caused by changes in ocean conditions and increased human beach activity. In collaboration with the Grunion Greeters Project and the California Department of Fish and Wildlife, the team evaluated oceanic environmental and ecological factors that affect grunion spawning patterns. Earth observation data products, including NASA Multi-scale Ultra-high Resolution Sea Surface Temperature (MUR SST) and Aqua Moderate Resolution Imaging Spectroradiometer (MODIS) chlorophyll-a (chl-a), were used to create time series of the California coastline and nearby Pacific Ocean from 2003 to 2018. Upwelling, sea surface current, air temperature, and harmful algal bloom (HAB) data were also considered to derive correlations between the above parameters and grunion spawning events. Analyzing how a changing ocean affects the California grunion will allow for more accurate predictive modeling of spawning behavior and will provide the knowledge base needed to protect this unique species.

**Keywords:**

Remote sensing, ocean color, time series analysis, habitat mapping, MUR, MODIS Aqua, sea surface temperature, marine conservation

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

***Study Location:*** Coastal California, CA

***Study Period:*** January 2003 – June 2018

***Community Concern:***

* The grunion plays a critical role in the marine food web. The fish acts as a versatile food source for marine animals, seabirds, and other fishes, and a population decrease of the grunion will negatively impact the species abundance at the higher trophic levels.
* It is thought that local environmental changes, such as beach grooming, coastal armoring, and anthropogenic beach activity, along with over-harvesting will continue to decrease the grunion population.
* Grunion runs are free for visitors to engage in and learn from, providing environmental education opportunities for children. However, if the grunion population is too low some beaches may have to be closed to these public activities, decreasing the accessibility of these educational programs.

***Project Objectives:***

* Create time series of sea surface temperature and chlorophyll-a for the entire coast of California and the nearby Pacific Ocean, in addition to time series for a wide array of *in situ* data
* Compare time series at different latitudes to determine if sea surface temperature and chlorophyll-a are significant factors affecting grunion spawning patterns
* Build a tool that partners can use to easily replicate the methods for future satellite and *in situ* data

***Previous Term:*** 2017 Summer (JPL) – Southern California Oceans

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Grunion Greeters Project** | Dr. Karen Martin, Professor of Biology, Pepperdine University | End User | Yes |
| **California Department of Fish and Wildlife** | Loni Adams, Marine Environmental Scientist | End User | Yes |

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

The Grunion Greeters Project is a collaboration of many organizations, including greater entities such as US Fish and Wildlife Service, California State Parks, and the California Coastal Coalition. The Grunion Greeters Project conducts citizen-science based data collection on grunion spawning sites where volunteers submit population assessments, build staging tables for embryonic hatching mechanisms, and study the effects of altered salinity. These observations are then submitted online via Grunion.org, where results and datasets are made available for use by scientists, beach managers and government agencies.

The California Department of Fish and Wildlife manages their marine protected areas and decides whether or not an outside project (recreation or restoration) implemented at the beach will impact the spawning areas. They make site-specific recommendations to avoid and minimize impacts to spawning habitat and incubation period, and use monitoring efforts to decide if other projects should be located at a different location.

***Project Benefit to End User***:

The time series maps will help the Grunion Greeters Project and other stakeholders predict areas where future grunion spawning may take place. The maps will also help the partners to save time and resources in guiding their citizen scientists’ collection of *in situ* data. The end user will have an improved ability to assess current management approaches and will be empowered to improve conservation management practices based on the results of this project. The California Department of Fish and Wildlife may incorporate the end results into a grunion management and conservation guidance document.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **Aqua MODIS** | Chlorophyll-a | Data from this satellite were processed and analyzed to create a time series movie of chlorophyll-a concentrations from 2003-2018 of the California coastline and nearby Pacific Ocean, and correlated with grunion data |

***Ancillary Datasets:***

Grunion Greeters Project citizen-science *in situ* data – This dataset contains the observed spawning locations and size of grunion runs, and was used for time series analysis and correlated with ocean conditions.

NASA Multi-scale Ultra-high Resolution (MUR) – These data were processed and analyzed to create a time series movie of sea surface temperature from 2003 to 2018 of the California coastline, and correlated with grunion data.

NASA Ocean Surface Current Analyses Real-time (OSCAR) – These data include sea surface current speed, direction, convergence, vorticity, and alignment data, and was used to create time series movie.

NOAA NCEI Climate Data – This dataset provides daily *in situ* air temperature along the west coast and was used for time series analysis and correlated with grunion data.

NOAA NCEI El Niño/Southern Oscillation (ENSO) Index – This dataset characterizes the periodic wind, sea surface temperature, atmospheric variations affecting climate in the Pacific Ocean, and was used for time series analysis.

NOAA NCEI Pacific Decadal Oscillation (PDO) Index – This dataset provides monthly indices on North Pacific sea surface temperature variability, and was used for time series analysis.

NOAA National Data Buoy Center – Standard Meteorological Data from buoys along the California coastline containing *in situ* water temperature was used for time series analysis, validation of satellite data, and correlated with grunion data.

NOAA Pacific Fisheries Environmental Laboratory (PFEL) Coastal Upwelling Indices – This dataset provides the latitudinal daily upwelling indices along the west coast of North America, and used for time series analysis and correlated with grunion data.

Southern California Coastal Ocean Observing System (SCCOOS) Harmful Algal Blooms (HABs) Data – This dataset provides *in situ* water temperature, chlorophyll-a, and harmful algae concentrations along the Southern California coastline, and was used for time series analysis, validation of satellite data, and correlated with grunion data.

***Software & Scripting:***

Esri ArcGIS – Data analysis, processing, and visualization

QGIS – Map creation and visualization

MATLAB – Data processing and statistical analysis

R – Data processing and analysis

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Time Series of Ocean Observations** | N/A | These time series will allow partners to see where historical ocean observations have changed in relation to grunion spawning and migration patterns. This will enhance management practices in determining which environmental factors may play a role in grunion migration patterns. | I |
| **Time Series Maps of Sea Surface Temperature and Chlorophyll-a** | Aqua MODIS | These maps will allow partners to predict future scenarios of grunion migration patterns from past temperature and chlorophyll changes and patterns. This will simplify and enhance management practices to help sustain the spawning habitat of the fish. | I |
| **Maps of Spawning Sites with Overlay of Environmental Conditions** | Aqua MODIS | These maps will assist partners to protect and establish regulation of the most suitable beaches for grunion spawning. | I |
| **Grunion Spawning Site Suitability Tool** | Aqua MODIS | This tool was built with MATLAB and will allow the partners to predict grunion spawning sites for a particular time period with current environmental factors. It incorporates correlations found associated with past environmental factors and grunion spawning events in a user friendly GUI platform. | IV |
| **Grunion Spawning Site Suitability Tool Tutorial** | N/A | This tutorial is a written, step-by-step instruction manual for the partners as a reference on how to use the Grunion Spawning Site Suitability Tool, including required inputs and expected outputs. | N/A |

**Project Handoff Package**

**Transition Plan:**

The results from this project were handed off to Dr. Karen Martin and Loni Adams by email and through a separate video conference during the last week of the term or in-person during closeout at JPL, depending on the time availability of the partners. During the hand-off, the team showed a presentation and a tutorial, so Dr. Martin can replicate the results in the future. Dr. Martin will share the project results with the beach managers with which she works closely. Loni will coordinate with her organization for a media post of the project results on the organization website.

*Software Release Plan*:

The team submitted the necessary paperwork to the DEVELOP National Program Office (NPO) during the term to begin the software release process. The team will inform the project partners of the software release process and that it may take up to 4-6 months. At the end of the term, the team will submit the final code for the proposed Grunion Spawning Site Suitability Tool to NPO. When the code is posted by NPO to the NASA DEVELOP GitHub account, the team will inform the partners where to find the tool and tutorial.

**Team POC:** Alexandra Jones, lexxii1456@gmail.com

**Software Release POC**: Alexandra Jones, lexxii1456@gmail.com

**Partner POC**: Dr. Karen Martin, karen.martin@pepperdine.edu; Loni Adams, loni.adams@wildlife.ca.gov

**Handoff Package:**

* Email of deliverables
  + Time Series Maps of Chlorophyll-a and Sea Surface Temperature
  + Time Series of Ocean Observations Maps of Grunion Spawning Sites with Overlay of Environmental Conditions
* In-person or videoconference presentation of results and methodologies
* DEVELOP deliverables
  + Project summary, tech paper, poster, PowerPoint presentation, video, study area shapefiles, website images

**References:**

Ehrlich, K. F., & Muszynski, G. (1982). Effects of temperature on interactions of physiological and behavioural capacities of larval California grunion: adaptations to the planktonic environment. *Journal of Experimental Marine Biology Ecology, 60*, 223-244.

Martin, K. (2004). Beach-spawning fishes, terrestrial eggs, and air breathing. *Physiological and Biochemical Zoology 77*(5), 750-759.

Martin, K. (2006). Introduction to grunion biology. Personal communication. 1-5. Retrieved from <http://grunion.pepperdine.edu/IntroductionToGrunionBiology.pdf>

Martin, K. (2015). Biodiversity: California grunion. *Urban Coast, 5*(1), 150-156.

Martin, K. L., Moravek, C. L., & Flannery, J. A. (2009). Embryonic staging series for the beach spawning, terrestrially incubating California grunion *Leuresthes tenuis* with comparisons to other Atherinomorpha. *Journal of Fish Biology*, *75*(1), 17-38.

Martin, K. L. M., Hieb, K. A., & Roberts, D. A. (2013). A Southern California icon surfs north: Local ecotype of California grunion, *Leuresthes tenuis* (Atherinopsidae), revealed by multiple approaches during temporary habitat expansion into San Francisco Bay. *Copeia, 4,* 729-739.

Roberts, D., Lea, R. N., & Martin, K. L. M. (2007). First record of the occurrence of the California Grunion, *Leuresthes tenuis*, in Tomales Bay, California: A northern extension of the species. *California Fish and Game 93*(2), 107-110.