**NASA DEVELOP National Program**

**Alabama – Marshall**

*Project Summary – Spring 2018*

**Puget Sound Water Resources**

*Evaluating Methods for Identifying and Monitoring Factors in the Puget Sound that Indicate Eutrophication and Hypoxia*

**VPS Title:** Oxygenless in Seattle: Identifying and Monitoring Eutrophication in the Puget Sound

**Project Team**

***Project Team*:**

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**Project Overview**

***Project Synopsis*:** Eutrophication and harmful algal blooms (HAB), which have become more prevalent in the Puget Sound since 2000, have led to negative impacts on water quality and wildlife. NASA DEVELOP at Alabama – Marshall partnered with the Pacific States Marine Fisheries Commission (PSMFC) Habitat Program to identify and map factors of eutrophication using data from NASA Earth observations. The products developed during this project will help the PSMFC Habitat Program determine areas at a higher risk of HAB events and further inform local decision-making practices and management of water resources.

***Abstract*:**

Dissolved oxygen levels have been declining in the Puget Sound since 2000 due to eutrophication, resulting in harmful algal bloom (HAB) events, which negatively impact water quality and wildlife in the area. Therefore, analyzing and identifying eutrophication and hypoxic events is important for water quality control and watershed management. The Puget Sound Water Resources team partnered with the Pacific States Marine Fisheries Commission (PSMFC) Habitat Program to create a HAB Factors Identification Tool, a HAB Hotspots Map, and a HAB Time Series Analysis using data from Sentinel-2 MultiSpectral Instrument (MSI), and Landsat 8 Operational Land Imager (OLI) from 2010–2017. The team validated the products with water temperature, turbidity, salinity, and chlorophyll-a concentration data collected from buoys located in the Puget Sound. Results will assist the PSMFC Habitat Program to fill geographic and temporal data gaps and to enhance local decision-making practices and management of water resources.

**Keywords:**

Sentinel-2 MSI, Landsat 8 OLI, dissolved oxygen, sea surface temperature, salinity, turbidity, harmful algal bloom

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

***Study Location:*** Puget Sound, WA

***Study Period:*** 2010 – 2017 (May – October)

***Community Concern:***

* Hypoxia and eutrophication have become more prevalent in the Puget Sound since 2000.
* Due to lower oxygen levels, HABs are impacting populations of sessile organisms, such as geoduck clams, which are important to the local economy.
* HABs increase potential for fish kill events, which indirectly impact other species in the area by posing a health risk if consumed.
* Domoic acid levels, produced by the algae strain *pseudo-nitzchia*, have been increasing during HAB events and are hazardous to human health.

***Project Objectives:***

* Provide the PSMFC with a resource to bridge spatial gaps in *in situ* data by determining the best algorithms to identify indicators of HAB events within the Puget Sound
* Aid project partners in enhance water quality management by identifying areas that are historically prone to showing indicators of HABs

**Partner Overview**

***Partner Organization:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Pacific States Marine Fisheries Commission, Habitat Program** | Fran Recht, Habitat Program Manager | End User | Yes |

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

The PSMFC aims to protect and manage fisheries in over five Pacific states through their Habitat Program, which focuses on the conservation and restoration of watersheds and estuaries. The Habitat Program has a non-voting seat on the Pacific Fishery Management Council, as well as on the Habitat Committee. They advise the Council on protection of essential fish habitats, where monitoring eutrophication and hypoxia is essential. The Habitat Program also provides water quality management advice to communities and organizations. Currently, seaplanes, ferries, and moored instruments are used to monitor eutrophication and hypoxia in the Puget Sound.

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

The PSMFC Habitat Program will use the results of this project to monitor factors indicative of eutrophication, specifically chlorophyll-a concentrations, turbidity, and sea surface temperature. Incorporating the most statistically accurate algorithms and sensors for each parameter within the Puget Sound region will allow the PSMFC to monitor these water quality indicators with greater spatial and temporal resolution and to pinpoint areas that may need further attention. This will provide PSMFC with more robust material for outreach programs and enhance their efforts towards improving water quality.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 8 OLI** | Surface Reflectance | Landsat 8 OLI spectral signatures were processed to identify turbidity and chlorophyll-a concentrations. |
| **Aqua MODIS** | Sea Surface Temperature | Aqua MODIS data were used to assess sea surface temperature. |
| **Sentinel-2 MSI** | Surface reflectance | Spectral signatures from Sentinel-2 MSI were used to identify turbidity and chlorophyll-a concentrations. |

***Ancillary Datasets:***

State of Washington Department of Ecology Marine Water Monitoring *in situ* buoy Chlorophyll-a Concentration, and Water Temperature data – Determine accuracy of algorithms and validate final maps

King County Mooring *in situ* buoy Chlorophyll-a Concentration, Turbidity, and Water Temperature data – Determine accuracy of algorithms and validate final maps

National Oceanic and Atmospheric Administration (NOAA) National Data Buoy Center *in situ* buoy

 Chlorophyll-a Concentration, and Water Temperature data – Determine accuracy of algorithms and validate final maps

***Software & Scripting:***

ACOLITE – Process Landsat 8 OLI and Sentinel-2 MSI imagery to determine chlorophyll-a concentrations and turbidity

Esri ArcGIS 10.4 – Process Landsat 8 OLI, Aqua MODIS, and Sentinel-2 MSI imagery, create Model Builder Tool, produce maps

Rstudio – Conduct statistical analysis to compare *in situ* and remotely sensed data

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **HAB Factors Identification Tool** | Aqua MODISLandsat 8 OLISentinel-2 MSI | This tool will be used to identify environmental suitability for HAB events. The partner will use the tool to pinpoint areas that may need more water quality resources. This tool complements the geographic and temporal limitations of *in situ* data collection. | N/A |
| **HAB Hotspots Map** | Aqua MODISLandsat 8 OLISentinel-2 MSI  | The partner will use the HAB Hotspots Map to identify areas that are historically prone to indicators of HAB events, and thus may require special monitoring and care because of their location and other variables. | N/A |
| **HAB Time Series Analysis** | Aqua MODISLandsat 8 OLISentinel-2 MSI  | This analysis gives the partner more information about identifying where HAB events tend to occur by showing how HAB suitability parameters change geographically within the Puget Sound. | N/A |

**Project Handoff Package**

**Transition Plan:**

HAB Factors Identification Tool, HAB Hotspots Map, HAB Time Series Analysis, tutorials, and deliverables will be shared with the end user via Google Drive folder at the end of the term. A conference call will be held to present findings from the project and field questions about products, and a virtual workshop will be conducted to demonstrate use of the tool.

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**Partner POC**: Fran Recht, franrecht@gmail.com

**Handoff Package:**

* HAB Factors Identification Tool
* HAB Hotspots Map
* HAB Time Series Analysis
* Tutorial for use of HAB Factors Identification Tool and HAB Time Series Analysis

**References:**

Anderson, D. M., Glibert, P. M., & Burkholder, J. M. (2002). Harmful algal blooms and eutrophication: Nutrient sources, composition, and consequences. *Estuaries, 25*(4), 704-726. doi:10.1007/bf02804901

Environmental Protection Agency. (2017). Marine water quality*. Salish Sea Report.* Retrieved from [www.epa.gov/salish-sea/marine-water-quality](http://www.epa.gov/salish-sea/marine-water-quality)

Moore, S. K., Bill, B. D., Hay, L. R., Emenegger, J., Eldred, K. C., Greengrove, C. L., . . . Anderson, D. M. (2015). Factors regulating excystment of Alexandrium in Puget Sound, WA, USA. *Harmful Algae, 43*, 103-110. doi:10.1016/j.hal.2015.01.005

Ogashawara, I., Alcântara, E., Curtarelli, M., Adami, M., Nascimento, R., Souza, A., . . . Kampel, M. (2014). Performance analysis of MODIS 500-m spatial resolution products for estimating chlorophyll-a concentrations in oligo- to meso-trophic waters case study: Itumbiara Reservoir, Brazil. *Remote Sensing, 6*(12), 1634-1653. doi:10.3390/rs6021634

Toming, K., Kutser, T., Laas, A., Sepp, M., Paavel, B., & Noges, T. (2016). First experiences in mapping lake water quality parameters with Sentinel-2 MSI imagery. *Remote Sensing*, *8*(8). Retrieved from <http://www.mdpi.com/2072-4292/8/8/640>

Trinh R. C., Fichot C. G., Gierach M. M., Holt B., Malakar N.K., Hulley G. & Smith J. (2017). Application of Landsat 8 for monitoring impacts of wastewater discharge on coastal water quality. *Frontiers in Marine Science, 4*:329. doi: 10.3389/fmars.2017.00329

Vanhellemont, Q., & Ruddick, K. (2015). Advantages of high quality SWIR bands for ocean colour processing: Examples from Landsat-8. *Remote Sensing of Environment, 161*, 89-106. doi:10.1016/j.rse.2015.02.007