**Lake Michigan Water Resources II**

*Utilizing Multispectral Satellite Imagery to Monitor and Predict the Displacement of Cladophora along the Milwaukee County Shoreline*

**VPS Title:** Stinky Business: Remediating *Cladophora* Accumulation on the Lake Michigan Shoreline

**Project Team**

***Project Team*:**

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***Advisors & Mentors*:**

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***Past or Other Contributors*:**

Jerrold Acdan

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**Project Overview**

***Project Synopsis*:** *Cladophora*, a green macroalgae, frequently washes up in thick, foul-smelling mats along the Lake Michigan shoreline near Milwaukee, Wisconsin, harboring bacteria toxic to wildlife and making the beaches less attractive to visitors during peak season. Each year, Groundwork Milwaukee, a nonprofit organization, seeks to earn a contract with the City of Milwaukee to remove *Cladophora* from local beaches. Using NASA and ESA Earth observations, chlorophyll-a algorithms, and surface water current data, the NASA DEVELOP Lake Michigan Water Resources II team created a predictive washup tool to assist Groundwork Milwaukee in efficiently managing their cleanup efforts.

***Abstract*:**

Changing lake conditions, such as rising temperatures and phosphorus cycling by invasive Dreissenid mussels, have made washup of the green macroalgae *Cladophora glomerata* a consistent problem on beaches in Milwaukee County, presenting a threat to both wildlife and the local economy. Groundwork Milwaukee (GWMKE), a nonprofit organization, seeks to remove *Cladophora* from beaches along the Milwaukee County shoreline. To aid GWMKE’s cleanup planning efforts, the previous NASA DEVELOP Lake Michigan Water Resources I team created a habitat suitability map for *Cladophora* and utilized bathymetry, nearshore structures, and population density to create a predictive washup map. Our team continued their work by creating a user-friendly ArcGIS tool that predicts where *Cladophora* is most likely to wash ashore. The new tool utilized chlorophyll-a spectral signatures as proxies for *Cladophora* detection from Landsat 8 Operational Land Imager (OLI). Sentinel-2 MultiSpectral Instrument (MSI) data was also investigated for this purpose, however, the results from Landsat 8 more closely matched *in situ* chlorophyll-a measurements for Lake Michigan. Surface water currents were incorporated to predict *Cladophora* transport. The tool processed data for the study period from June to September 2016 to 2018 and the outputs were compared with *in situ* data of *Cladophora* washup. With the assistance of the Predictive Washup Tool, GWMKE will be able to more accurately predict the location of *Cladophora* washup and effectively manage their future cleanup efforts, making the beaches safer and more enjoyable for the community.

**Keywords:**

*Cladophora*, Groundwork Milwaukee, remote sensing, Landsat 8, Sentinel-2, chlorophyll-a, surface water current modeling, predictive tool

***National Application Areas Addressed:*** Water Resources

***Study Location:*** Western shore of Lake Michigan, bordering Wisconsin (WI), Illinois (IL), and Indiana (IN)

***Study Period:*** 2016 – 2018 (June – September)

***Community Concern:***

* A recent surge in *Cladophora* growth has resulted in an accumulation of algal mats on Lake Michigan’s western shores, creating nuisances and socioeconomic challenges to nearby communities.
* These algal masses can result in malodorous conditions that deter people from visiting the beach and can promote bacterial growth toxic to humans and wildlife if ingested.
* The City of Milwaukee places a high priority on *Cladophora* cleanup, including issuing a yearly contract for organizations to clean up the algae mats; organizations that wish to earn this contract must demonstrate a previous commitment to *Cladophora* cleanup.
* Current methods to remediate *Cladophora*, including visually inspecting beaches for the algae, are time-consuming and inefficient.

***Project Objectives:***

* Detect floating *Cladophora* from multispectral satellite imagery utilizing chlorophyll-a as an indicator
* Compare the efficacy of two multispectral satellite sensors for chlorophyll-a detection
* Predict the trajectory of *Cladophora* transport by modeling seasonal surface water currents
* Provide decision support to project partner by identifying areas where *Cladophora* is likely to wash ashore

***Previous Term:*** 2018 Summer (ARC) – Lake Michigan Water Resources

**Partner Overview**

***Partner Organization:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Groundwork USA,**  **Groundwork Milwaukee** | Deneine Christa Powell, Executive Director; Lawrence Hoffman, GIS Program Manager | End User | Yes |

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

Remediating *Cladophora* requires excessive time and resources due to difficulties in identifying washup locations and removing the algae. Cleanup efforts involve visiting each beach and visually inspecting whether *Cladophora* has washed ashore. To dispose of *Cladophora*, cleanup teams must rake the algae from the beaches, haul it out in large garbage bins, and transport it to the local landfill. The process is labor intensive as Milwaukee’s beaches are often below steep bluffs. The City of Milwaukee encourages sustainable *Cladophora* cleanup and will reward an organization with a contract to continue cleanup efforts. GWMKE seeks to earn the contract with the City of Milwaukee so that the organization can hire youth to assist with the cleanup and compost the algae, instead of transporting it to the landfill. To improve its remediation process by removing the time-consuming step of visually inspecting beaches, GWMKE aims to acquire a tool that will allow program leaders to direct cleanup efforts towards beaches with the highest density of *Cladophora*.

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

The *Cladophora* Predictive Washup Tool will improve the efficiency of GWMKE’s cleanup efforts by identifying locations where *Cladophora* is likely to wash up. The results will provide the resources for GWMKE to acquire Milwaukee’s yearly cleanup contract while also introducing members of GWMKE and the broader Milwaukee community to the capabilities of NASA and ESA Earth observations.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 8 OLI** | Chlorophyll-a, FAI | Chlorophyll-a spectral signatures were used to detect floating *Cladophora* for use in the *Cladophora* Predictive Washup Tool. Results from chlorophyll-a algorithms were compared to FAI outputs. |
| **Sentinel-2 MSI** | Chlorophyll-a, FAI | Chlorophyll-a spectral signatures were used to detect floating *Cladophora*. Results from chlorophyll-a algorithms were compared to FAI outputs. |

***Ancillary Datasets:***

NOAA Great Lakes Observing System Great Lakes Coastal Forecasting System – surface water current data for modeling *Cladophora* transport

Groundwork Milwaukee *Cladophora* locations – *in situ* *Cladophora* washup data for calibrating the Predictive Washup Tool

***Software & Scripting:***

Collector for ArcGIS – collect *in situ* data for calibrating *Cladophora* Predictive Washup model

ESRI ArcGIS Pro 2.2.0 – create a *Cladophora* Predictive Washup tool, which included mosaicking, cloud masking, and calculating chlorophyll-a values for satellite imagery, then tracking *Cladophora* movement by surface water currents

NetCDF Operators – average modeled surface water current data over a desired time period

SNAP – perform atmospheric correction on Sentinel-2 scenes

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| ***Cladophora* Predictive Washup Tool** | Landsat 8 OLI | This tool identifies areas where *Cladophora* is likely to wash up on the Lake Michigan shoreline in Milwaukee County. Groundwork Milwaukee can use this tool for guidance when planning *Cladophora* cleanup efforts. | I |
| ***Cladophora* Predictive Washup Tool Tutorial** | N/A | This written tutorial explains the *Cladophora* Predictive Washup Tool for ease of future use by Groundwork Milwaukee. | N/A |

**Project Handoff Package**

**Transition Plan:**

The team shared project deliverables and end products with Groundwork Milwaukee at the end of the term using NASA Large File Transfer. Results of the project were presented to the partner through a video conference at the end of the term.

**Team POC:** Jashvina Devadoss, jashvina@berkeley.edu

**Partner POC**: Lawrence Hoffman, lawrence@groundworkmke.org

**Handoff Package:**

* Project Summary
* Technical Paper
* Project Video
* Poster
* Presentation
* Shapefiles
* *Cladophora* Predictive Washup Tool
* *Cladophora* Predictive Washup Tool Tutorial

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