Examine the weight of variables involved in the development of harmful algal blooms and recommend potential monitoring areas in Oregon

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Background and Reasons for Study

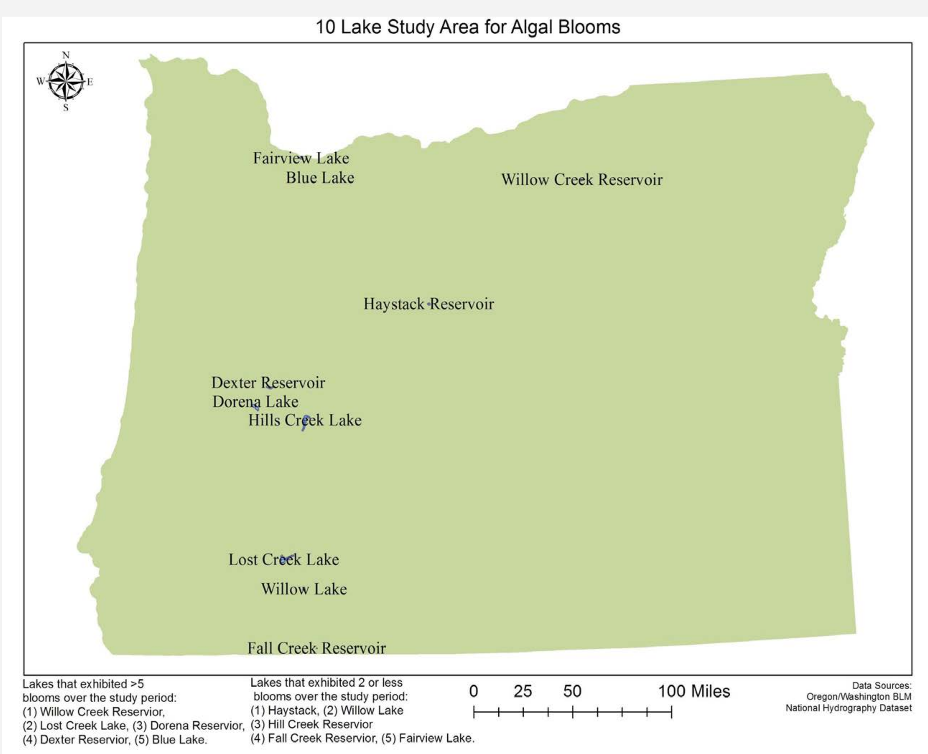
- The number and intensity of freshwater harmful algal blooms is increasing in the United States. This is of concern because harmful algal blooms produce toxins that are harmful to both the environment and humans (Weirich & Miller, 2014).
- Humans can be exposed to harmful algal blooms through accidental consumption of contaminated natural waters, through consumption of drinking water, and consumption of contaminated food (Weirich & Miller, 2014). These harmful algal blooms can also affect humans economically by increasing treatment costs for drinking water and by hurting industries that depend on clean water (United States EPA, 2017).
- As algal blooms decay, they consume the oxygen in water. This results in dead zones, which can lead to death of aquatic animals and contribute to a loss of biodiversity (Weirich & Miller, 2014).
- Monitoring for harmful algal blooms is not mandatory and is inconsistently done due to a lack of funding (Oregon Health Authority, 2016).
- There is a lot of research to be done to predict and identify bodies of water in Oregon that are at risk of developing harmful algal blooms (Oregon DEQ).

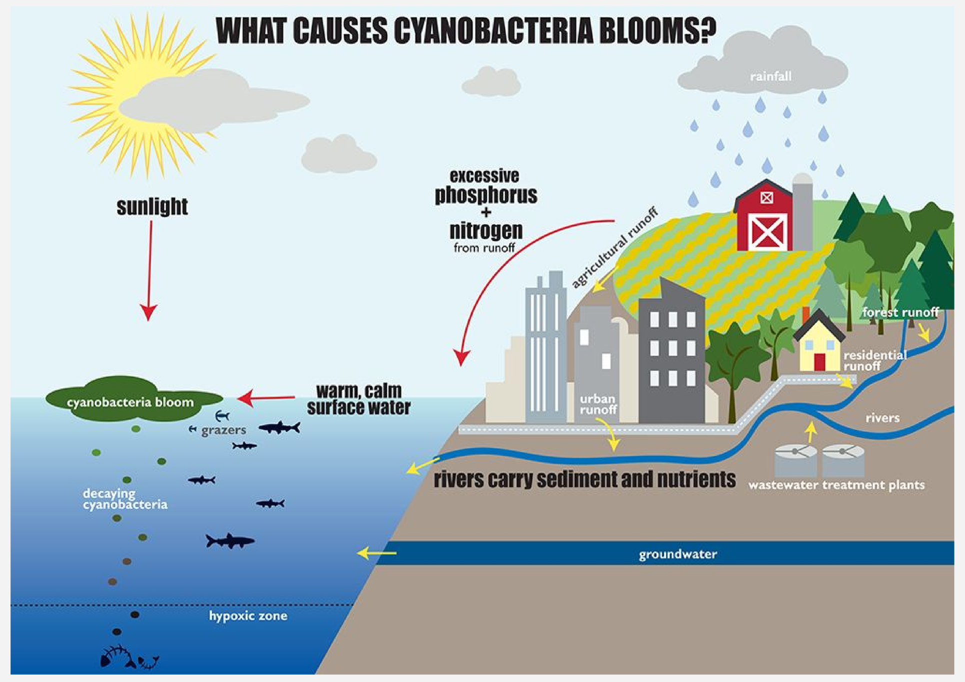
Research Question

- How do temperature, precipitation, and increased nutrient input contribute to the development of algal blooms?
- Can these variables be used to *predict* the development of algal blooms?

Methods

- We looked at water bodies that were monitored by the Oregon Health Authority from 2009 to 2013. We selected the five lakes that had five or more blooms over this time period.
- We then matched each of these 5 lakes with a lake that was also monitored by the Oregon Health Authority from 2009 to 2013. These matched lakes were chosen based off the closest in euclidean distance to one of the five original lakes and a lake that had 2 blooms or less in this time period.





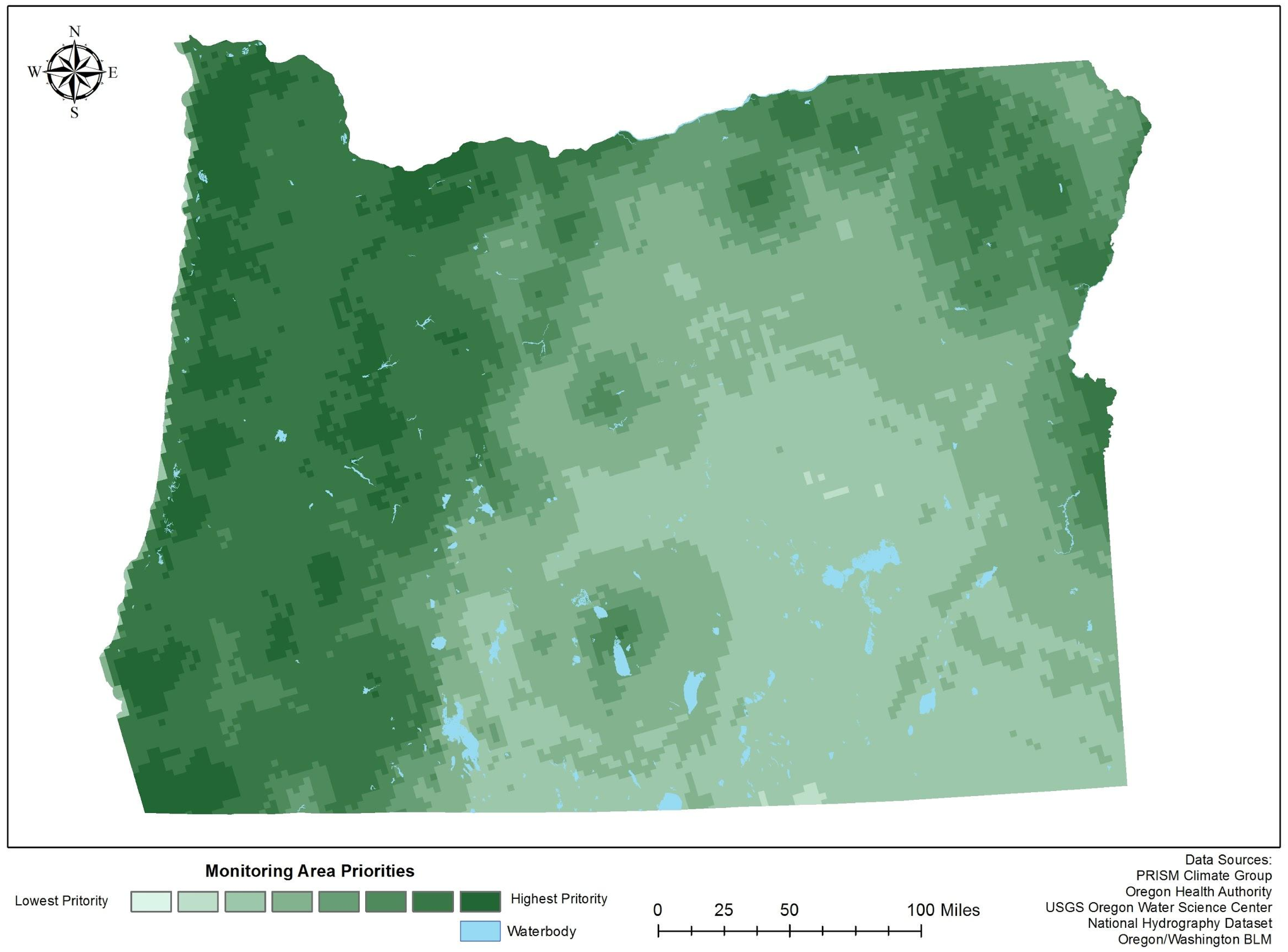
Source: State of the Lake. Lake Champlain New York/Vermont 2015

- The factors that are known to contribute to the formation of harmful algal blooms are: sunlight and warm temperatures, warm and calm surface waters, and phosphorus and nitrogen nutrient input (Lake Champlain Basin Program, 2015).

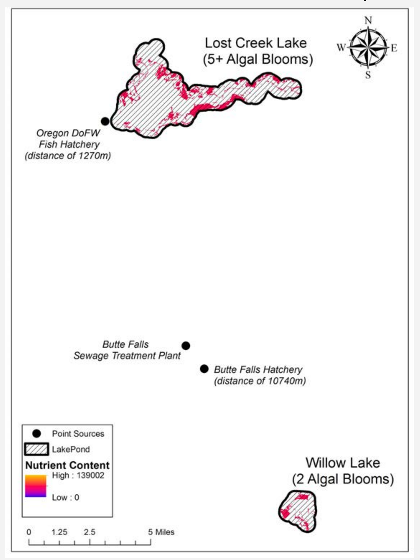
- We analyzed the factors of sunlight and warm water with ambient temperature data; the factor of calm water with wind speed data; and the factor of nutrient input with nutrient estimations and precipitation data - precipitation can transport nutrients into water bodies.
- We compiled ambient temperature data from the PRISM Climate Group. The advisory date for each algal bloom was used to organize and graph average daily temperatures for the 2 weeks preceding the bloom. The resulting graph was used to find the largest 5 day temperature shift before the bloom as well as the average temperature for the preceding 2 weeks.
- We compiled wind speed data from the National Renewable Energy Laboratory. We overlayed the wind shape file with the lakes layer and used the identify tool to identify the wind power class for each lake location. Each wind power class represented a range of wind speeds in miles per hour. This gave us an estimate of annual average wind speed for each lake location in miles per hour.
- Precipitation data was compiled from the PRISM Climate Group website. We calculated the total precipitation from March to May in inches for each lake and each year from 2009 to 2013. We also counted the number of days between March and May when the precipitation was greater than or equal to 10mm at each lake for each year.
- We used data from the USGS National Water Quality Assessment for phosphorus and nitrogen nutrient input. We used the "buffer" tool to create a 500 meter buffer around each lake. This buffer was used to clip the nutrient input layer. The Cell Statistics tool was then used to extract a sum of potential inputs.

Prioritization of Algal Bloom Monitoring in Oregon

Based on total spring precipitation, average summer temperatures, and distance to nutrient point source



Buffer & Cell Statistics Result for Nutrient Inputs.



- Distance to the closest point source was also used to estimate potential nutrient inputs. The Euclidean Distance tool was used to determine the closest point source and the distance in meters.
- To determine if there was a significant difference for each factor (temperature, precipitation, wind, nutrient input) between lakes with blooms and lakes without blooms we performed t-tests for each variable. Before performing t-tests we performed f-tests to test that the variance of the two groups were equal.

- For temperature and precipitation, we grouped the data into two groups: lakes that had blooms and lakes that did not. A t-test was done for each factor and each year, between 2009 and 2013, and between bloom groups for all 5 years combined.
- The wind and nutrient input data did not have a time span like the temperature and precipitation data. Therefore, we grouped the data for these factors differently. This data was grouped by the 5 lakes that had greater than or equal to 5 blooms from 2009 to 2013 and the 5 lakes that had less than or equal to 2 blooms over this time period.
- After collecting and analyzing the seven variables, none were found to be statistically significant. Three variables were found to be more reliable than the others and had means that differed in the direction that the literature predicted. These three variables were: 2 week average temperature preceding the bloom, cumulative spring precipitation, and distance to the closest point sources.
- We did an overlay of these three variables to produce a map that displays areas in Oregon where monitoring of algal blooms should be prioritized.
    - Temperature rasters for Oregon in June, July, August, and September of 2011 were downloaded from PRISM Climate group. The cell statistics tool was used to find the mean of these four rasters. This output raster was reclassified to assign values from 1 to 10, with 10 representing the highest average temperatures.
    - Monthly total precipitation rasters for Oregon in March, April, and May were downloaded from PRISM Climate group. The cell statistics tool was used to find the sum of these three rasters. This output raster was reclassified to assign values from 1 to 10, with 10 representing the highest total precipitation.
    - The Euclidean Distance tool was used to create an output raster of distance from a point source using the point source pollution layer from USGS Oregon Water Science Center. This output raster was reclassified to assign values from 1 to 10, with 10 representing cells that were the closest to a point source.
    - The sum of the three reclassified rasters was calculated using the cell statistics tool. Higher values indicate areas where monitoring of algal blooms should be prioritized.

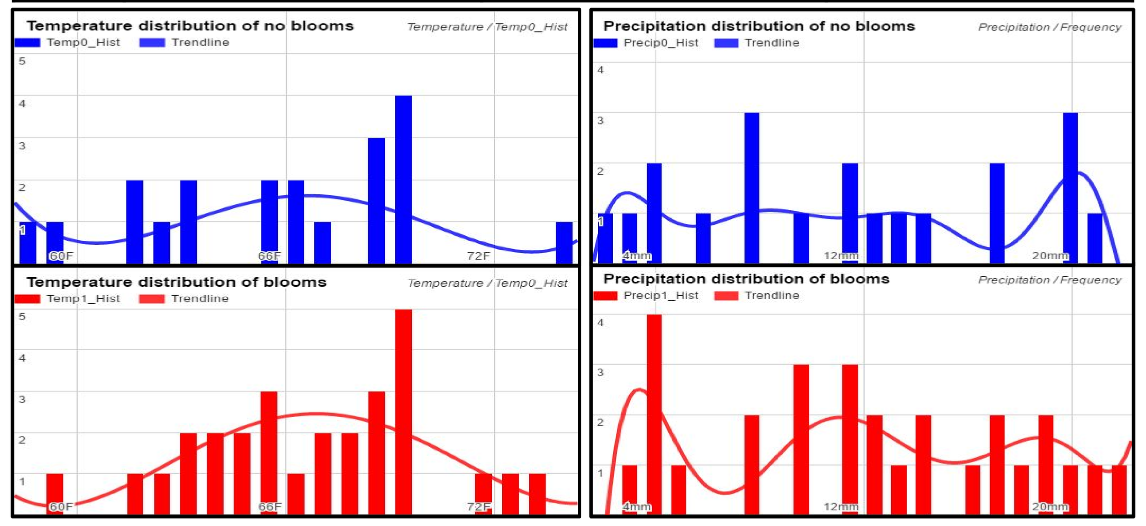
Results

- None of the seven variables we analyzed were found to be statistically significant. Three variables had means that differed in the direction that the literature predicted. These three variables were: 2 week average temperature preceding the bloom, cumulative spring precipitation, and distance to the closest point sources.
- Temperature fluctuations preceding the bloom and number of extreme precipitation events both differed in the direction expected. These variables however showed less differentiation between categories compared to the three variables listed above.
- The nutrient input variable showed a correlation to blooms opposite of what has been demonstrated by other studies and was not statistically significant.
- Wind showed little deviation and was statistically insignificant.
- To further test our variables we applied a Generalized Additive Model. Applying various combinations of the 3 strongest variables, distance to point source and temperature resulted in the highest predictability. However, these 2 variables could only predict 10% of the variability in the development of blooms.

The table below shows:

- Lakes with blooms had a higher average temperature than lakes without blooms
- Lakes with blooms had higher average spring precipitation compared to lakes without blooms
- Lakes with blooms were, on average, closer to recorded point sources than those without blooms.

	2-week Temperature-No Bloom	2-week Temperature-Bloom	Spring Precipitation-No Bloom	Spring Precipitation-Bloom	Distance to PS-No Bloom	Distance to PS -Bloom
Sample Size (n)	20	28	20	28	5	5
Unit	Degrees Fahrenheit	Degrees Fahrenheit	Millimeters	Millimeters	Meters	Meters
Range (r)	(58.57 - 73.98)	(58.5 - 73.11)	(2.07 - 20.77)	(2.61 - 21.38)	(4.15 - 36773)	(273 - 7616)
Average (u)	65.58	66.34	11.08	11.64	11,657	2,438
Bloom Correlation	Positive	Positive	Positive	Positive	Negative	Negative
p-value	0.47		0.747		0.21	



Conclusion

- The number and intensity of harmful algal blooms in freshwaters is increasing in the United States and in Oregon. Monitoring of harmful algal blooms is important for both human health and environmental health.
- Algal bloom monitoring is expensive and funding is limited in Oregon. Limited resources can lead to difficult decisions about what areas in the state should be monitored. The map produced in this project displays areas in Oregon where monitoring of harmful algal blooms should be prioritized. This prioritization is based on high total spring precipitation, high average summer temperatures, and close distance to nutrient point sources. Funding resources should first be used to monitor lakes in the highest priority areas.
- Harmful algal blooms are predicted to increase with the changing climate, making these a more prevalent environmental and human health concern (United States EPA, 2013). Monitoring of these blooms will be an important strategy to mitigate climate change health concerns.
- There are known variables that contribute to the formation of harmful algal blooms including sunlight and warm temperatures, warm and calm surface waters, and phosphorus and nitrogen input. Working to reverse human caused climate change as well as limiting phosphorus and nitrogen inputs could reduce the number and intensity of harmful algal blooms observed in the future.
- This project was not successful at predicting where harmful algal blooms will form in Oregon.

Recommendations

- There is still a lot of research to be done in order to predict and identify bodies of water in Oregon that are at risk of developing harmful algal blooms (Oregon DEQ).
- One of the limitations of our project was the small sample size of ten lakes. The number of lakes included in the study was limited by the number of lakes for which the Oregon Health Authority had consistent data. We recommend an increase in funding for monitoring of lakes in order to increase the sample size for future studies.
- Future studies for monitoring recommendations for algal blooms could include calculations of distance to highly populated areas or areas with vulnerable populations. This would allow for prioritization of water bodies where the most people or vulnerable people would be affected by a bloom.
- We recommend policy changes for increased regulations, monitoring, and consequences for out of compliance point-sources near Oregon water bodies to reduce runoff and potentially reduce the occurrence of harmful algal blooms.
- Collaboration with other states, private entities, and other nations that are having algal bloom issues could reveal new information and tools they are using to monitor and solve their problem.
- The use of an appropriate additive statistical model in future analysis may be a helpful step for looking at the complex relationships between variables that contribute to the formation of harmful algal blooms.

Example of Algae Bloom Satellite Image, Lake St. Clair, Michigan/Ontario. Source: Nasa 2015

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