The background of the slide is a light gray gradient with several realistic water droplets of various sizes scattered across it. The droplets have highlights and shadows, giving them a three-dimensional appearance.

HARMFUL ALGAL BLOOM SMART DEVICE APPLICATION AND FIXED CAMERA MONITORING: USING MACHINE LEARNING TECHNIQUES FOR CLASSIFICATION OF HARMFUL ALGAL BLOOMS

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600+ Mile Long Ohio River Blue-Green Algae Bloom, Summer 2015

Toxic algae on the Ohio River

An algae bloom has been visible on nearly 700 miles of the Ohio River since it was first detected on Aug. 19. The toxin microcystin has been measured at high levels in many parts of the river. The Ohio EPA issues recreational “no contact” advisories when levels reach 20 ppb.



OHIO RIVER TOXIC ALGAE LEVELS

| Date | Location | River mile | Microcystin level (ppb) |
|----------|------------------------|------------|-------------------------|
| Sept. 16 | Fish Creek, W.Va. | 114 | 150 |
| Sept. 9 | Marietta, Ohio | 172 | 250 |
| Sept. 3 | Athens Boat & Ski Club | 200 | 130 |
| Sept. 9 | Point Pleasant, W.Va. | 265 | 250 |
| Sept. 9 | Huntington, W.Va. | 310 | 69 |
| Sept. 9 | Portsmouth, Ohio | 357 | 590 |
| Sept. 9 | Cincinnati | 470 | 1,900 |

Source: Ohio River Valley Water Sanitation Commission; Ohio EPA

STEVE LOPEZ / STAFF



Harmful Algal Bloom Smart Device Application (HAB App)



Advantages

- Smart devices are ubiquitous and crowd-sourcing approach is suitable
- Extensive reach over other methods
- Results are immediate
- Low-cost

GREEN VS. BLUE-GREEN ALGAE CLASSIFIER

- The HAB APP uses a supervised machine learning classifier to distinguish between the hue-saturation-value color histograms of green and blue-green algae using correctly classified training images.
- The smart device is then “trained” to distinguish between these, giving probability estimates for an unclassified test image.
- User then examines algae microscopically and, with assistance from a machine learning algorithm, follows a dichotomous key* for classification.



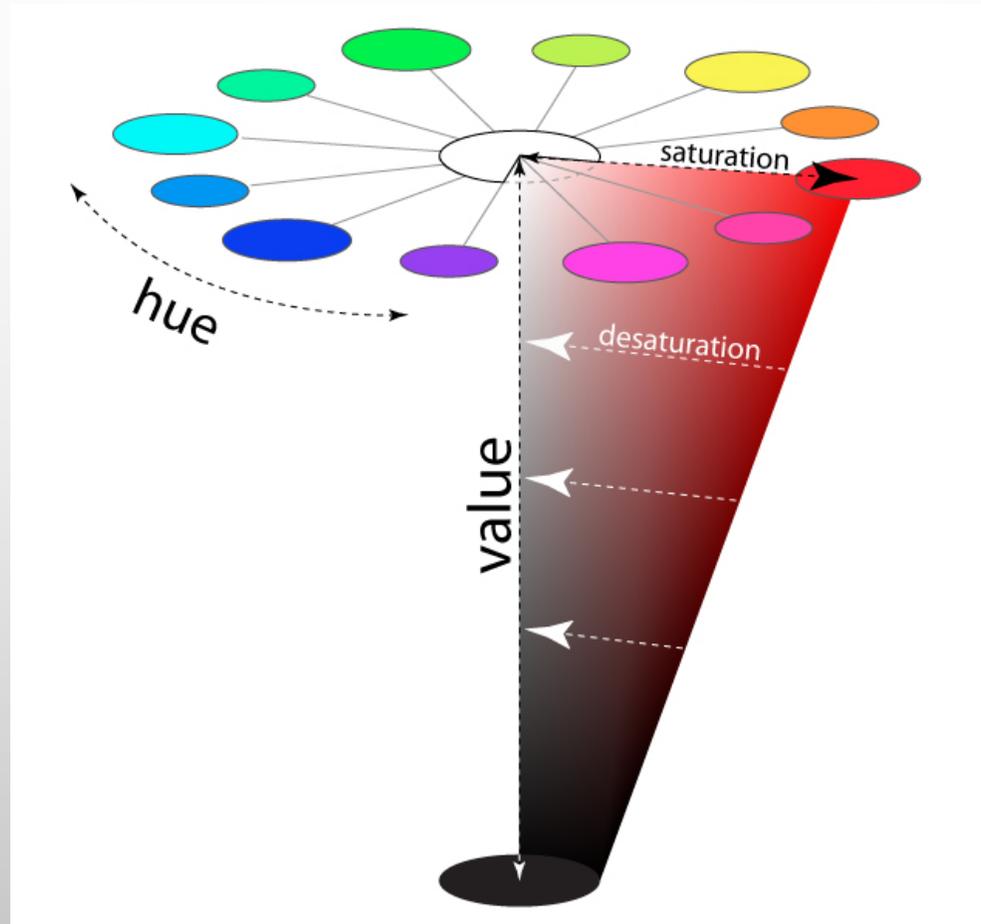
Smart Device Microscope

*Dichotomous key developed at NKU (Steinitz-Kannan, M. and Nienaber, M.) included in the application.

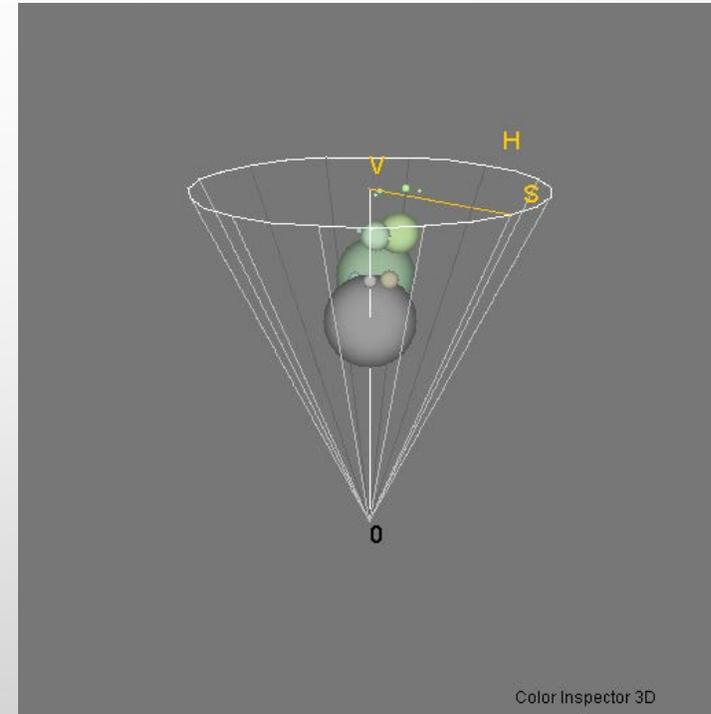
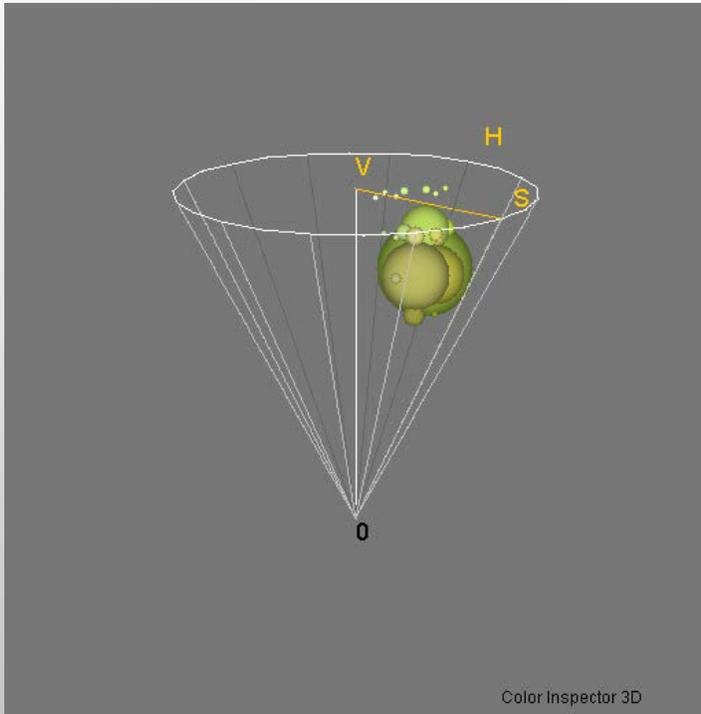
GREEN VS. BLUE-GREEN ALGAE



HUE-SATURATION-VALUE COLOR SPACE

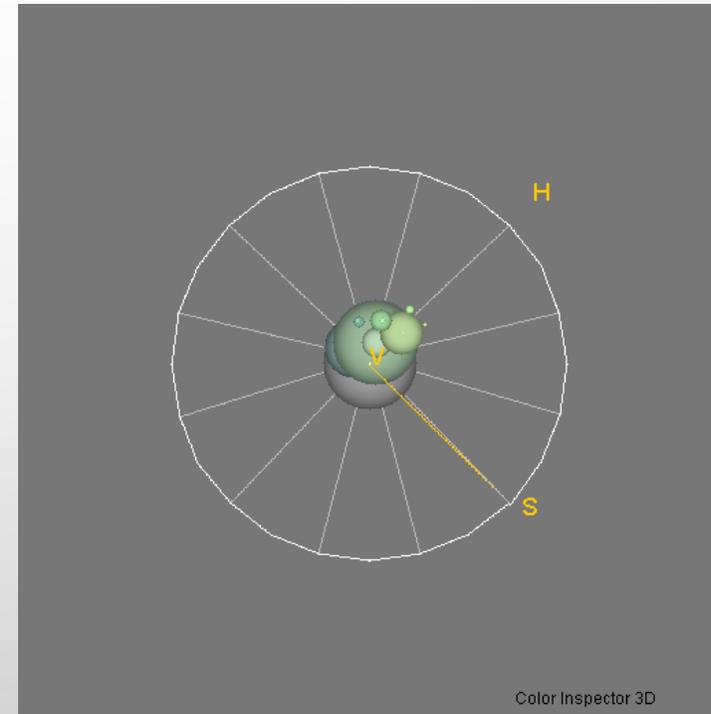
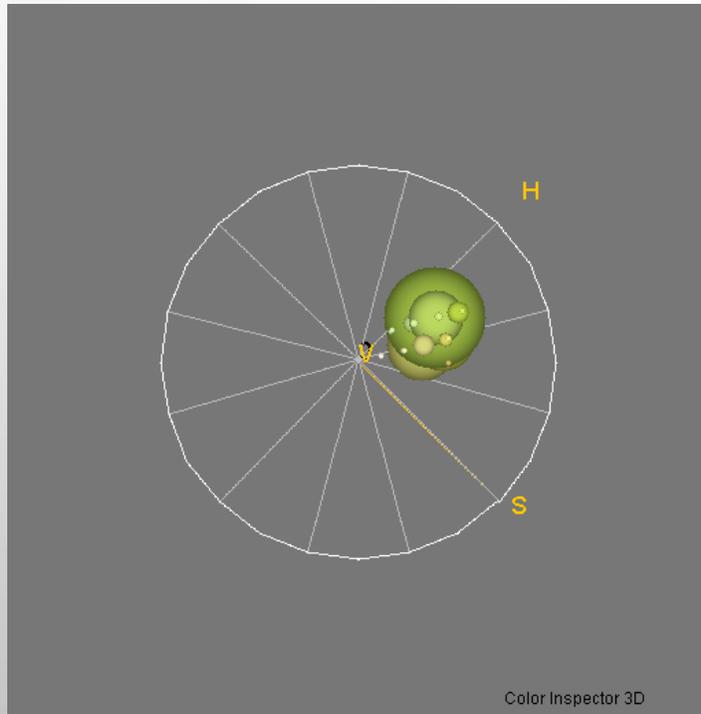


GREEN VS. BLUE-GREEN ALGAE

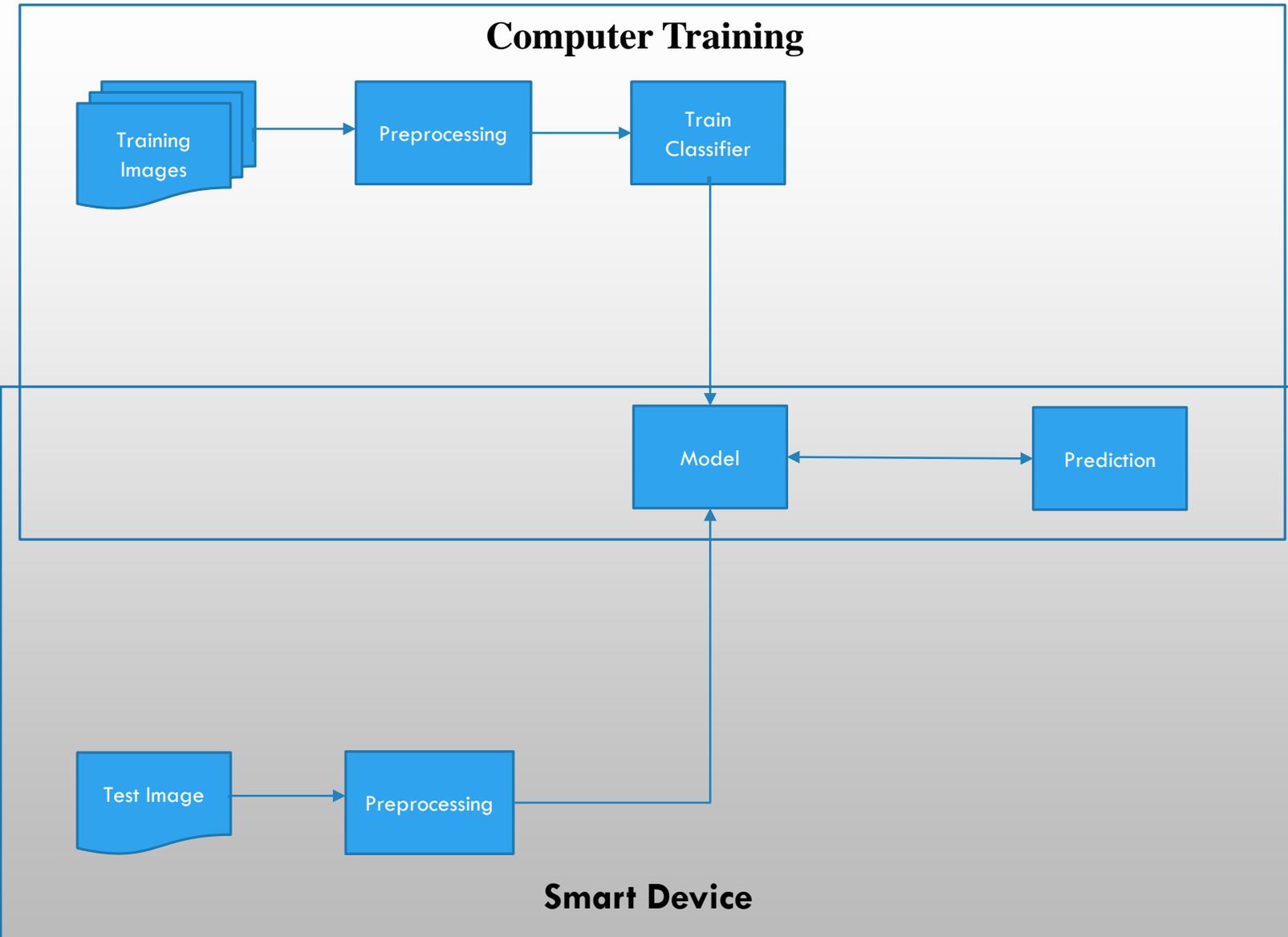


Hue-Saturation-Value Color Histograms

GREEN VS. BLUE-GREEN ALGAE



Hue-Saturation-Value Color Histograms



**Green Algae
Training Images**



**Blue-Green Algae
Training Images**



Machine Learning
Model

Test Image

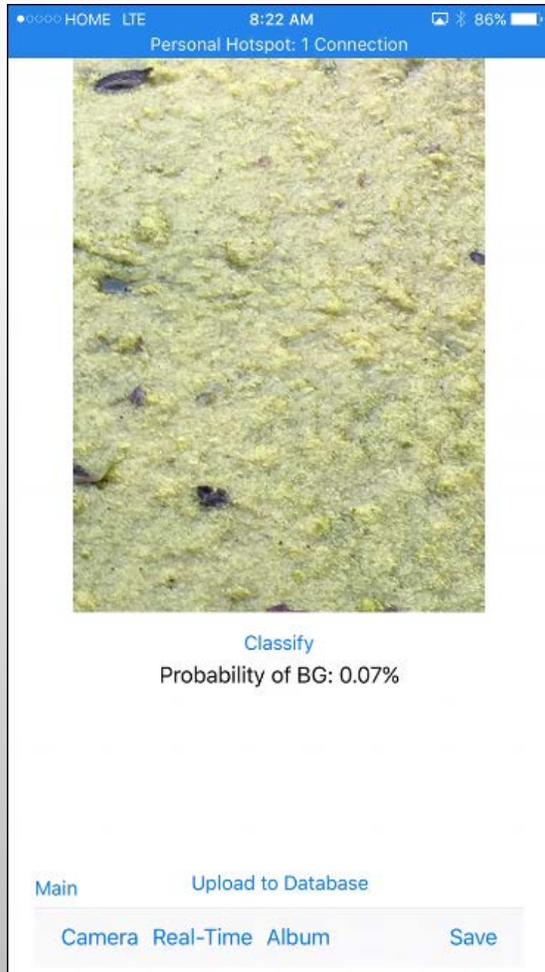


Smart Device

Classification

Probability of BG:
99.71%

SMART DEVICE CLASSIFICATION (IPHONE-BETA)



PERFORMANCE

| Confusion Matrix (70/30) n=52 | | Predicted | |
|-------------------------------------|----------------|-----------|----------------|
| | | Green | Blue- Green |
| Actual | Green | 6 | 0 |
| | Blue- Green | 0 | 9 |

95% Confidence Interval: (0.78,1)

Assuming a representative random sample of test images, we can be 95% confident that the accuracy is greater than 78%.



FIXED CAMERA MONITORING

- High Definition Security Camera with WiFi capability
- Powered by plug-in connection or solar array
- Images sent to server hourly during daylight hours

FIXED CAMERA SITES

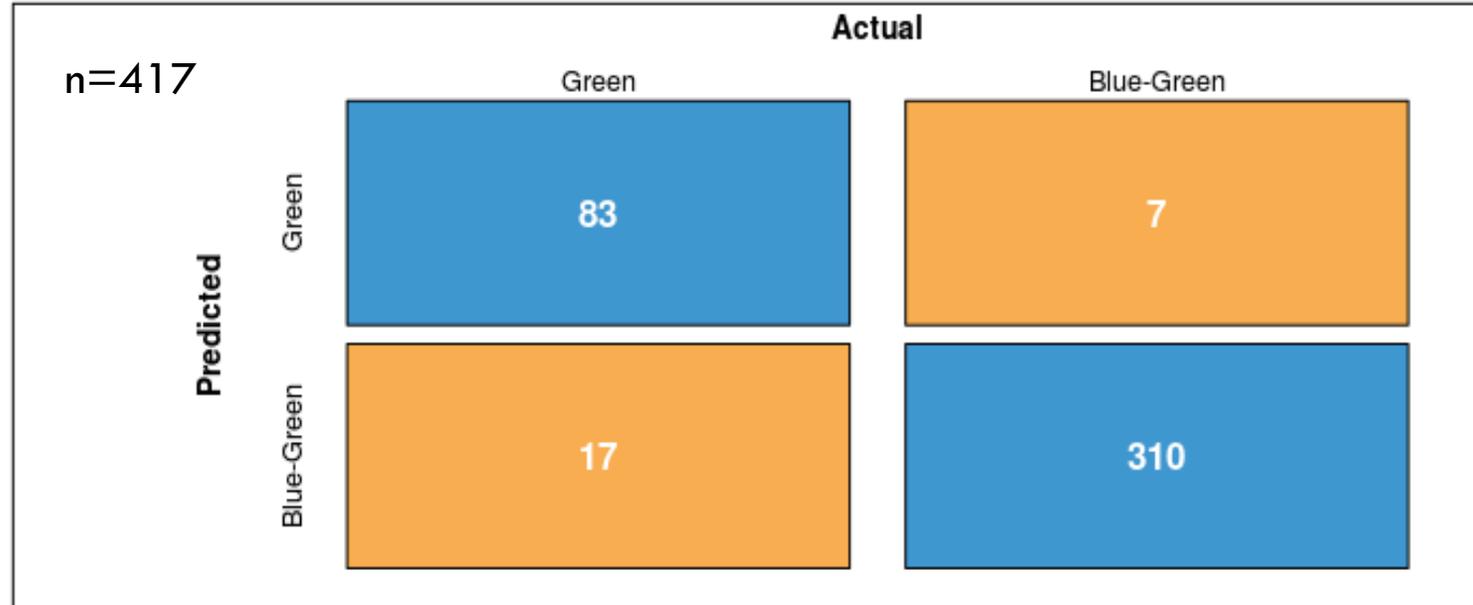
- LAKE HARSHA (EAST FORK) IN CLERMONT COUNTY, OH – 22,000 ACRE RESERVOIR SUPPLYING 6 MILLION GALLONS PER DAY OF DRINKING WATER AND SOURCE OF RECREATIONAL ACTIVITIES
- OHIO RIVER IN DAYTON, KY – QUEEN CITY RIVERBOATS
- OHIO RIVER IN CALIFORNIA, KY – THOMAS MORE COLLEGE FIELD STATION
- KENTUCKY LAKE – WESTERN KY (PLANNED)
- OHIO RIVER AT GREENUP & BYRD LOCKS AND DAMN – EASTERN KY (PLANNED)
- DISCOVERY LAKE – NC (PLANNED)
- CHARLES RIVER – MA (PLANNED)
- DELAWARE RIVER – KS (PLANNED)
- ATHENS, GREECE (PLANNED)

FIXED CAMERA SITES



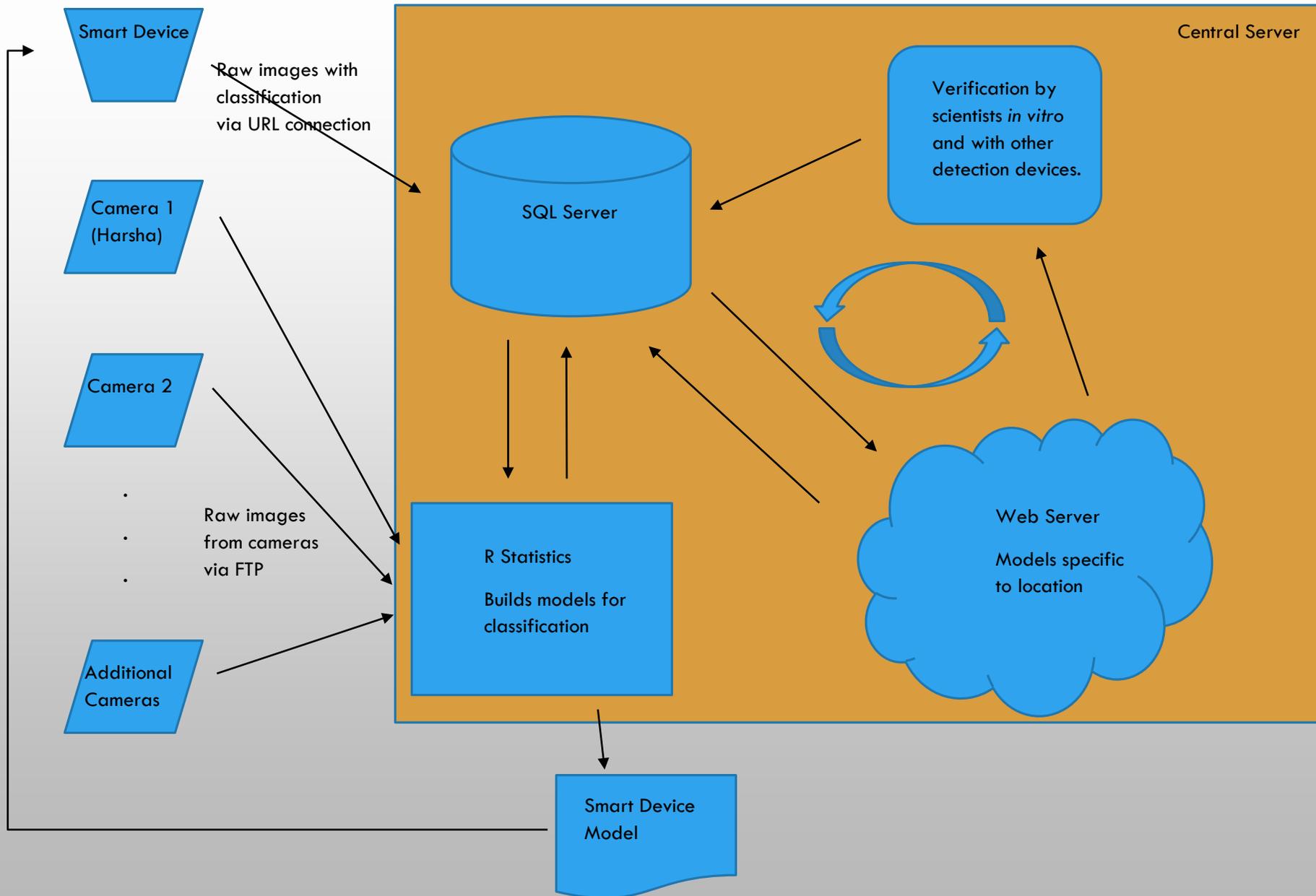
PERFORMANCE

Harsha SVM Classification Confusion Matrix



DETAILS

| | | | | |
|----------------------------|-----------------------------|---------------------------|-----------------------|--------------------|
| Sensitivity 0.83 | Specificity 0.978 | Precision 0.922 | Recall 0.83 | F1 0.874 |
| | Accuracy 0.942 | | Kappa 0.837 | |

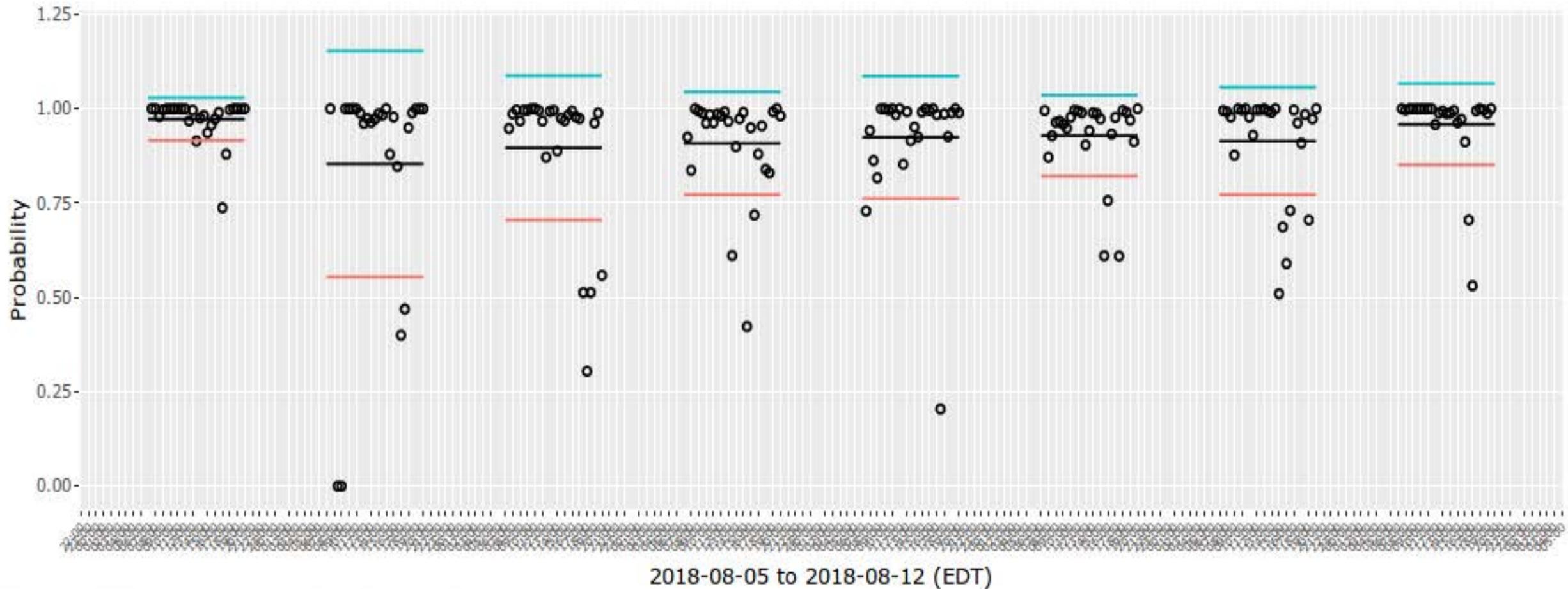


METHODS: AGENCY AND UNIVERSITY SCIENTISTS WILL ASSIST IN OPTIMIZING THE ALGORITHM BY EXTRACTING SAMPLES FROM SITES FROM WHICH IMAGES HAVE BEEN TAKEN TO VERIFY THE PRESENCE (AND AMOUNT) OF BLUE-GREEN ALGAE *IN VITRO* AND WITH OTHER DETECTION DEVICES.



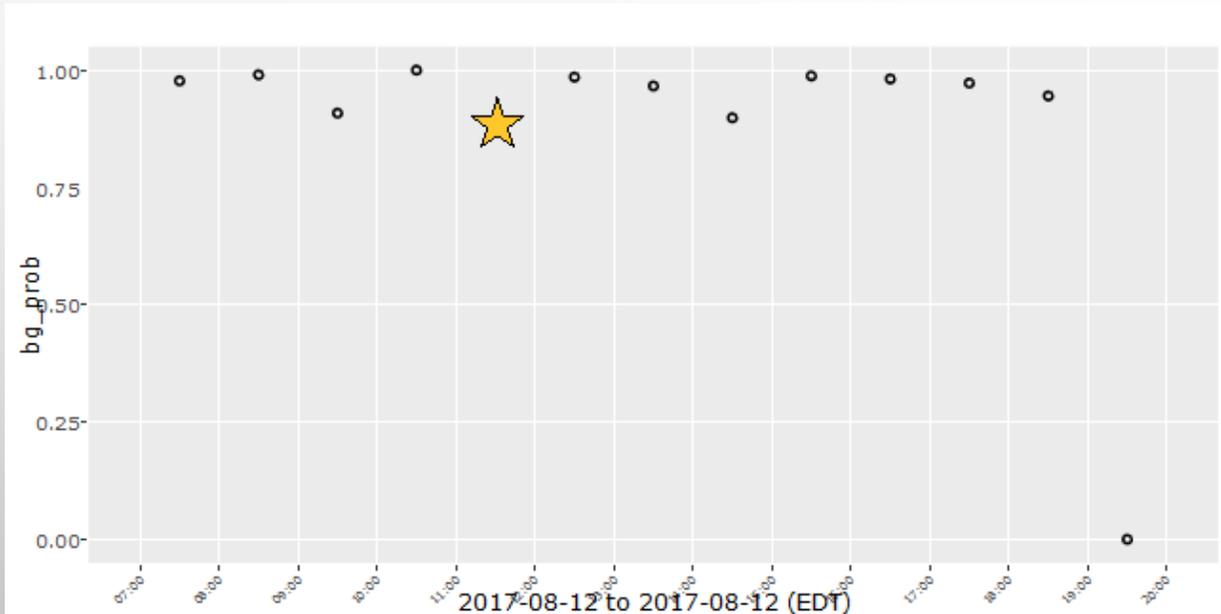
CURRENT MONITORING – WEBSITE

[HTTPS://MATHSTAT.NKU.EDU/HAB](https://mathstat.nku.edu/hab)



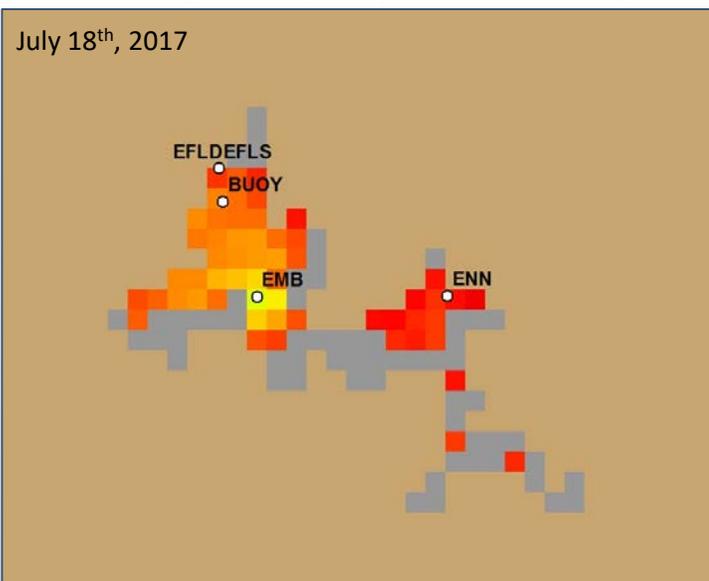
CURRENT MONITORING – WEBSITE

[HTTPS://MATHSTAT.NKU.EDU/HAB](https://mathstat.nku.edu/hab)



Lake Harsha, Aug 12, 2017, 11:30 a.m.
High probability of a HAB (confirmed).

Satellite Imaging



Estimated Cell Counts

EFLD/EFLS = 1,023,293 cells/ml

BUOY = 676,083 cells/ml

EMB = 323,594 cells/ml

ENN = 1,258,925 cells/ml

BOUY Site Fixed Camera Station

July 18th, 2017 at 10:30 am



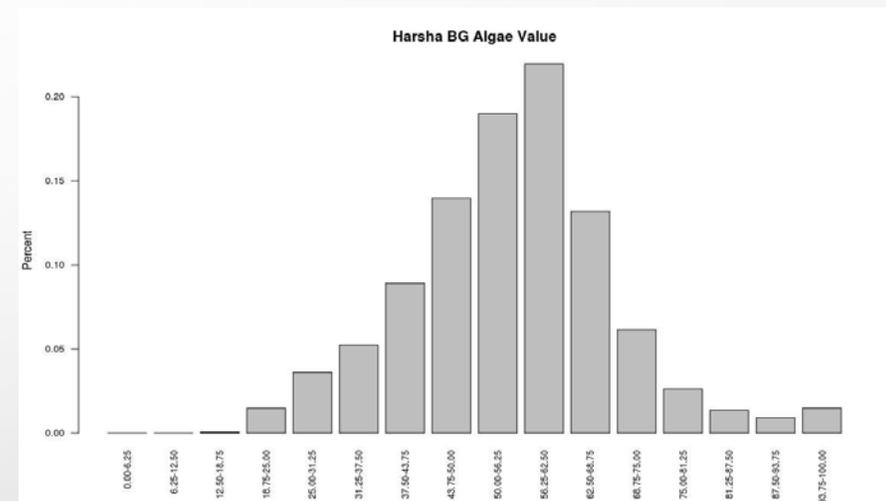
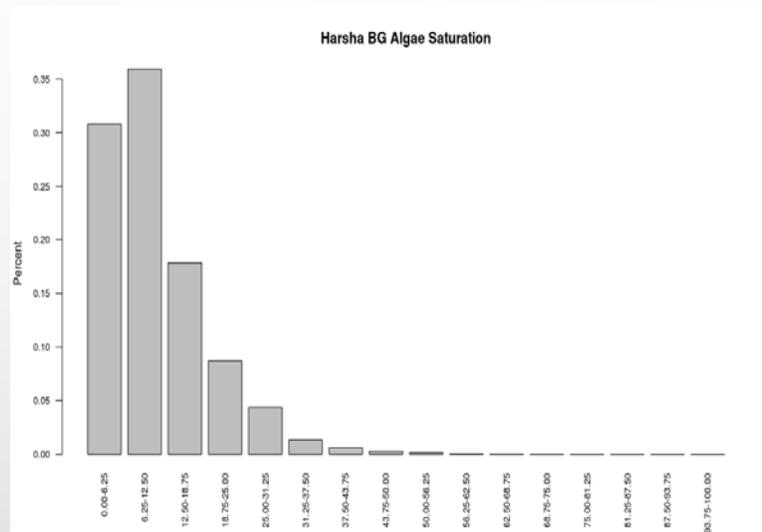
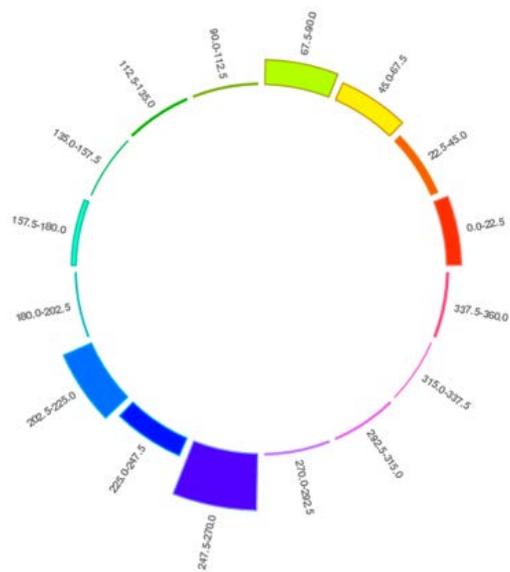
Fixed Camera Prediction of Cyanobacteria

Camera Prediction:

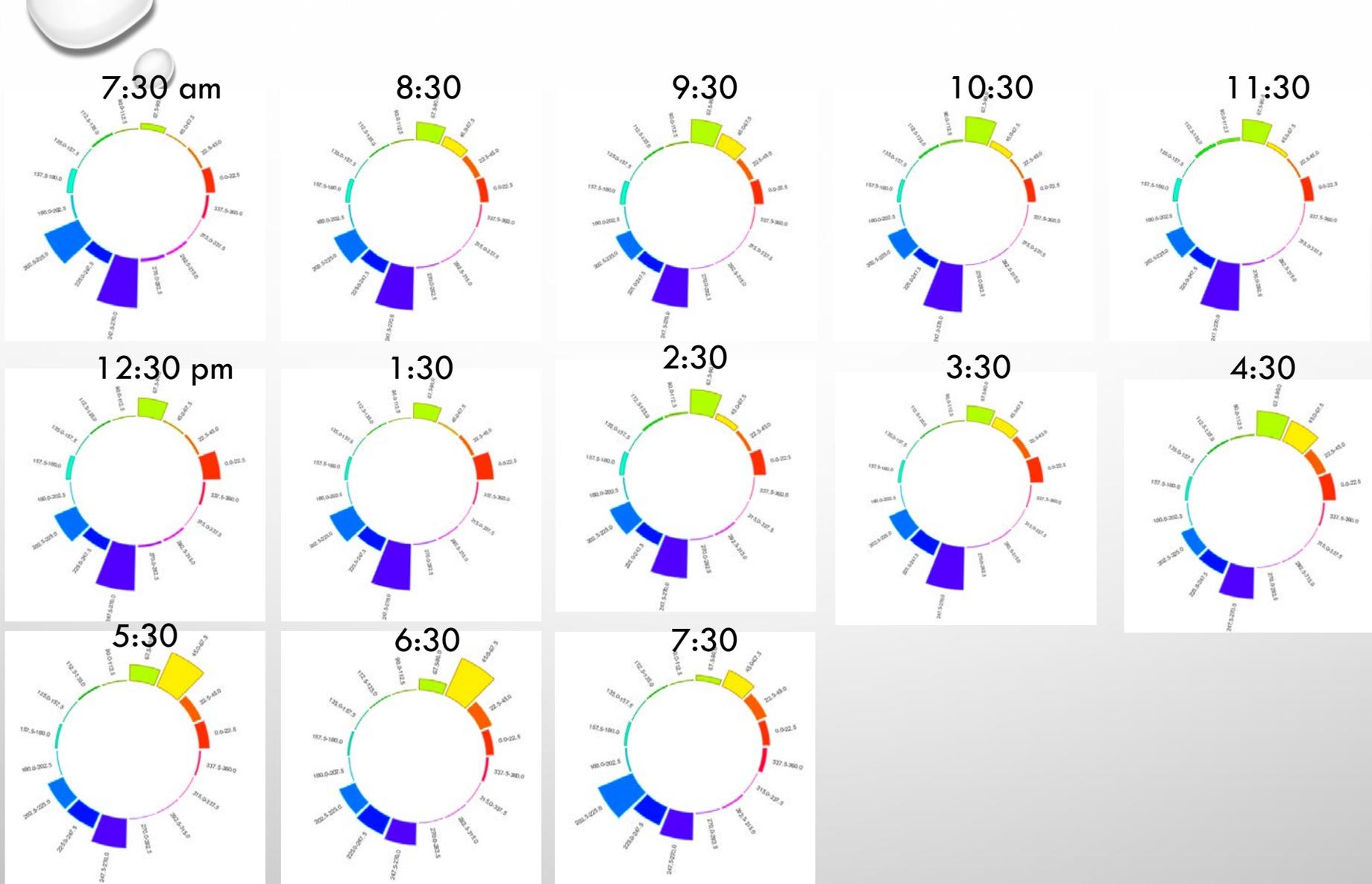
10:30 am - 98.3% Probability of Bluegreens

11:30 am 100% Probability of Bluegreens

Comparison of Sentinel-3 satellite imaging estimation and fixed camera algorithm on Lake Harsha, Clermont County, OH.

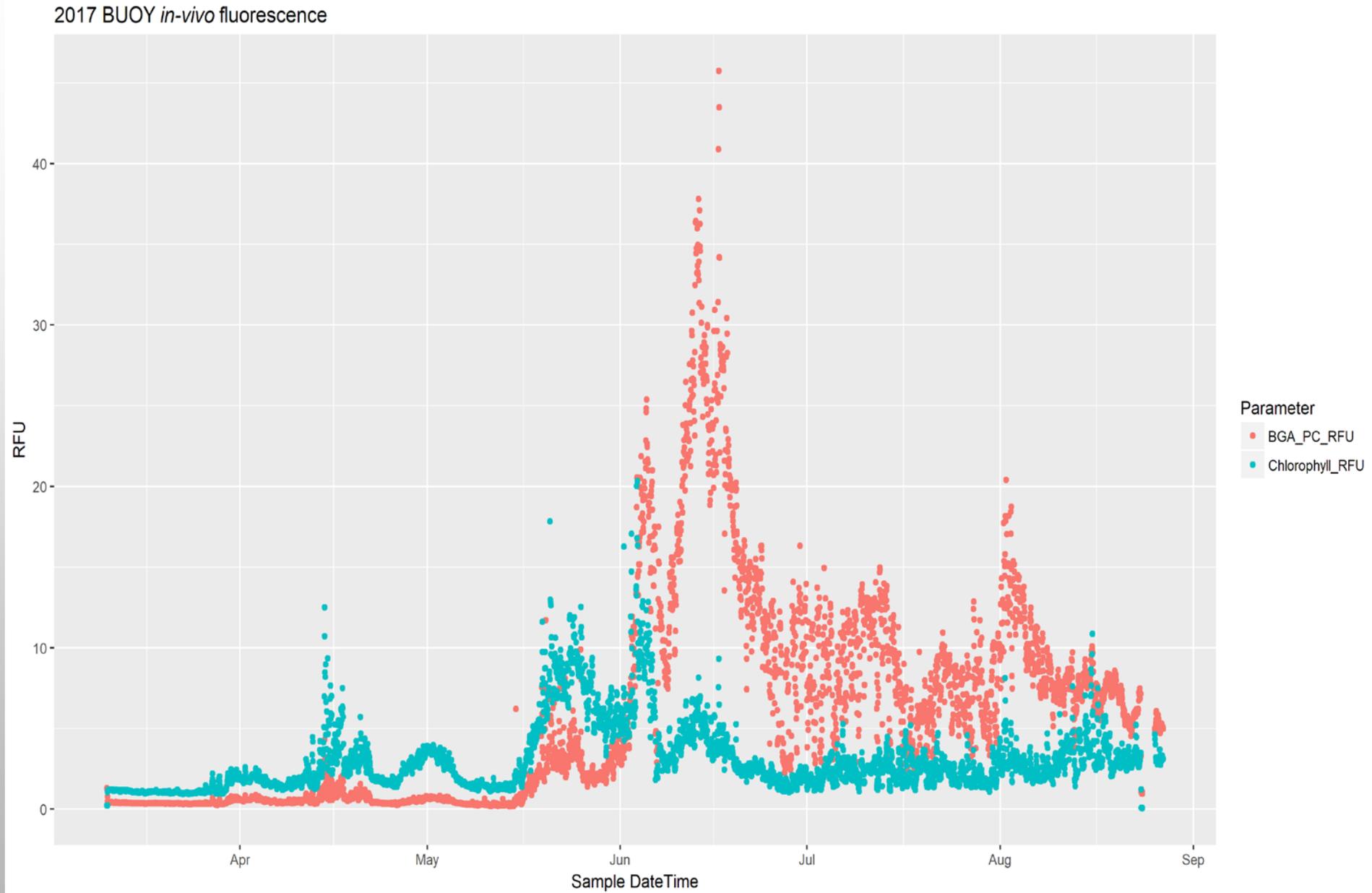


Hue-Saturation-Value Color Distributions for Lake Harsha – In Bloom
07/18/17 – 08/13/17



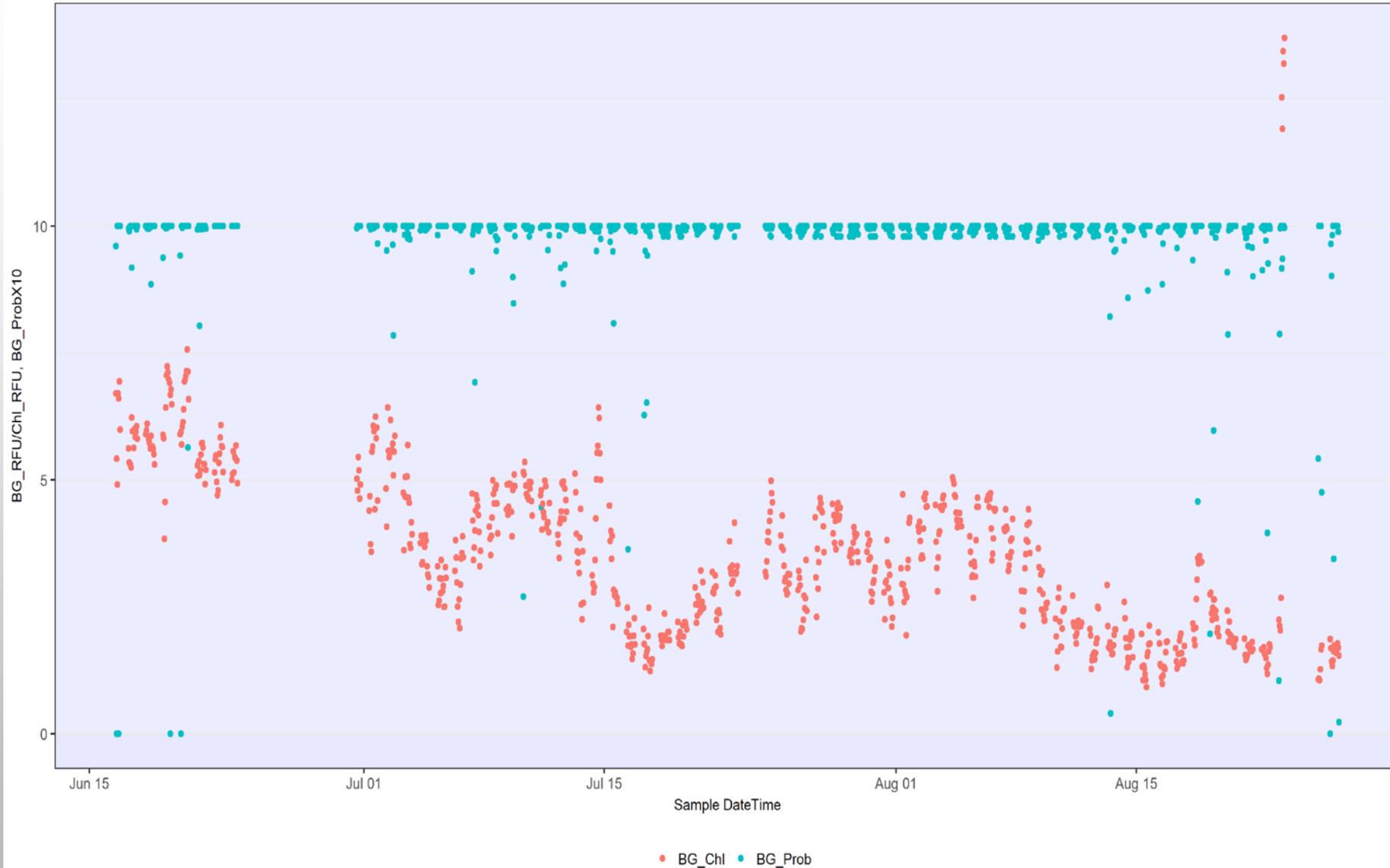
Hourly Hue Color Variation for Lake Harsha – In Bloom
07/18/17 – 08/13/17

BOUY *In Vivo* Fluorescence



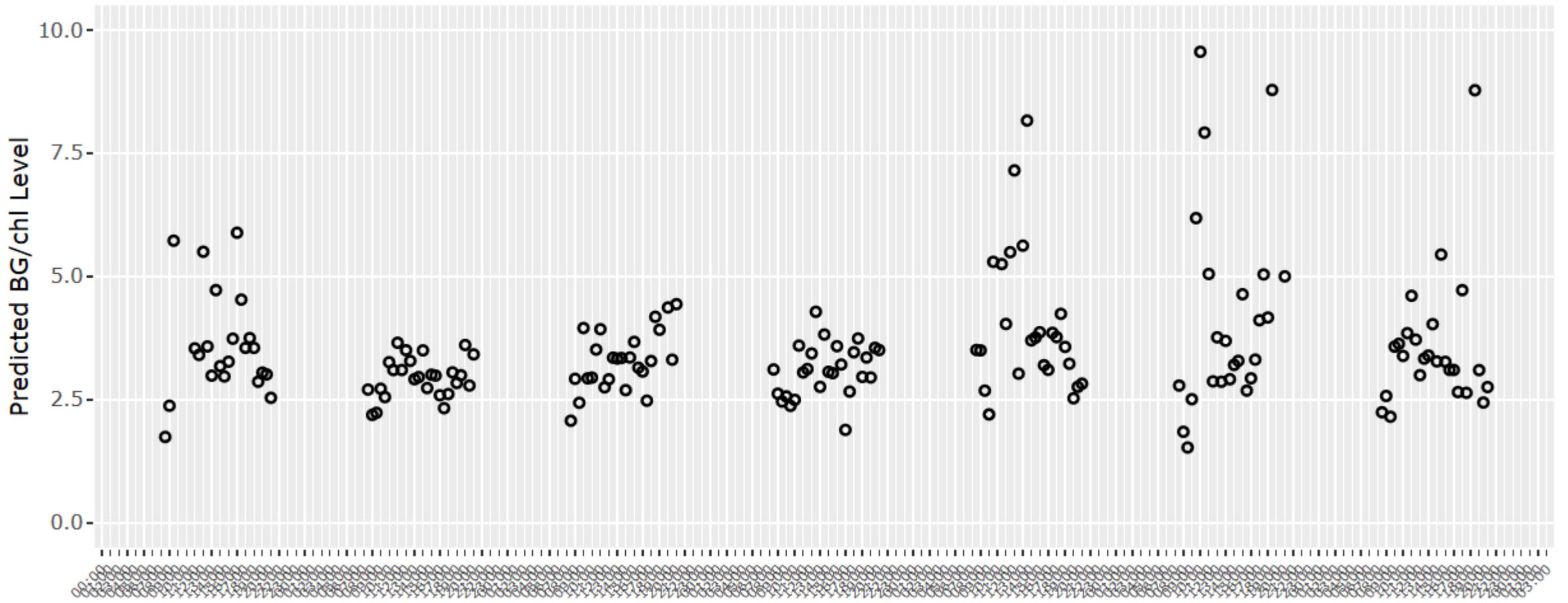
BOUY *In Vivo* Fluorescence vs Blue Green Probability X10

2017 BOUY *in-vivo* fluorescence BG_RFU/Chl_RFU and BG_Prob x 10



CURRENT MONITORING – WEBSITE

[HTTPS://MATHSTAT.NKU.EDU/HAB](https://mathstat.nku.edu/hab)



PLANNED EXTENSIONS

OVERALL

- PRINCIPAL COMPONENT ANALYSIS TO IMPROVE ACCURACY
- CHANGE BINARY TO TERNARY CLASSIFIER TO CORRESPOND TO WORLD HEALTH ORGANIZATION HAB CELLS/ML RISK LEVELS

SMART DEVICE APPLICATION

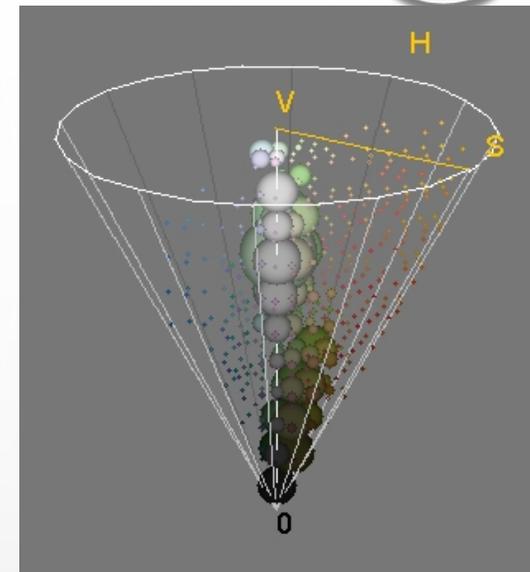
- AUTOMATIC CLASSIFICATION AT THE MICROSCOPIC LEVEL*
- CHANGE INDIVIDUAL IMAGES TO SEVERAL IMAGES – “WAVE THE DEVICE” MODE
- STANDARD OPERATING PROCEDURE FOR TAKING IMAGES TO AVOID GLARE/OCCCLUSION

MONITORING

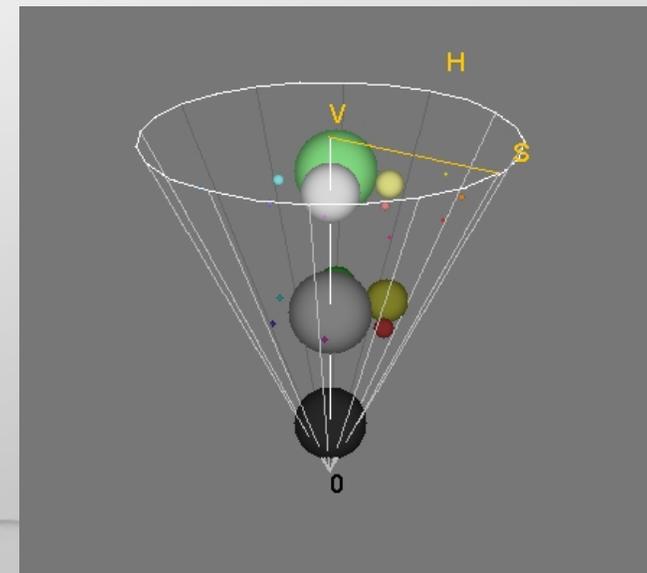
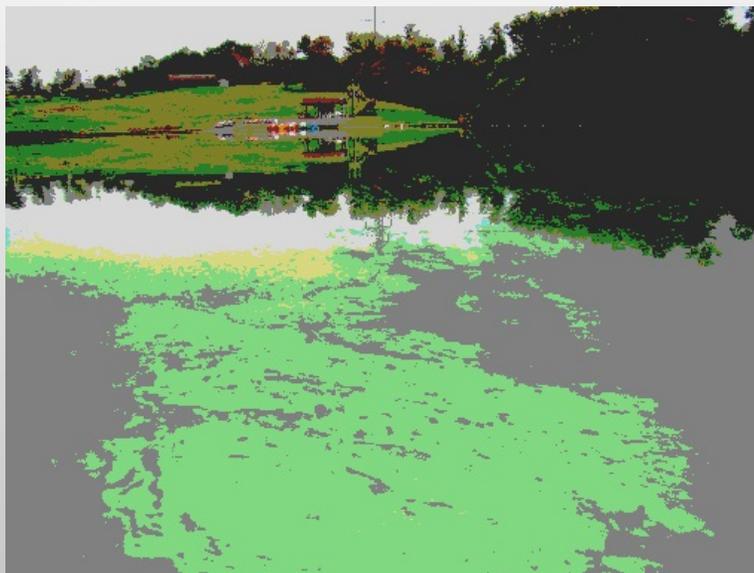
- ADD FIXED CAMERA STATIONS
- STANDARD SET-UP PROCEDURE TO AVOID GLARE/OCCCLUSION

*96.6% classification accuracy of microalgae by shape and color (Coltelli, *et. al.*, 2013)

Principal Component Analysis



Anabaena bloom
Camp Ernst Lake
Boone County, KY
October, 2014

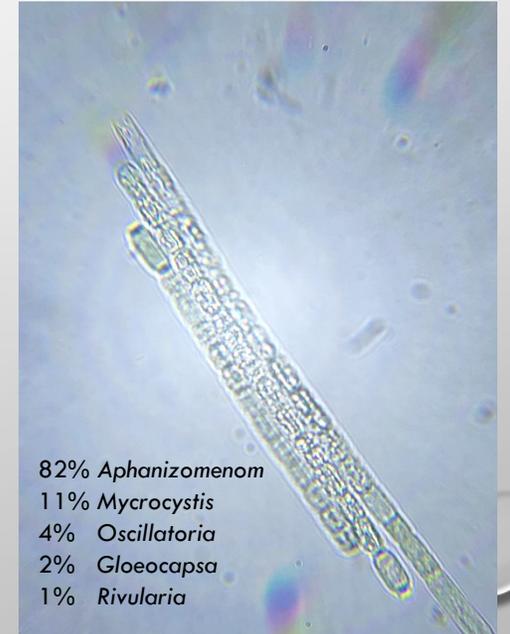
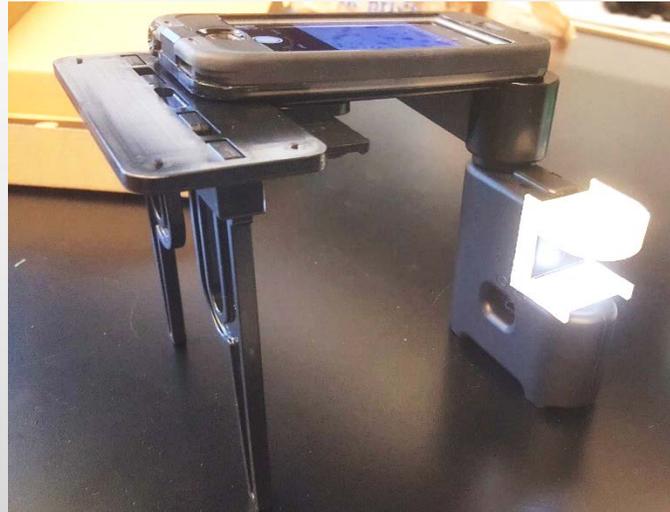


Planned Microalgae Extension

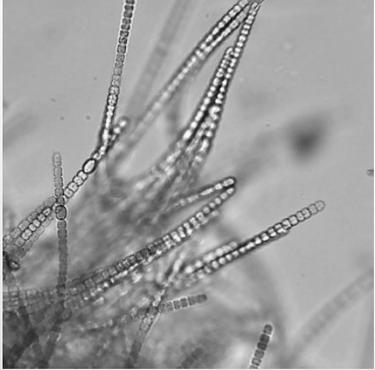


Aphanizomenon bloom
Big Bone Lake
Boone County, KY
February, 2017

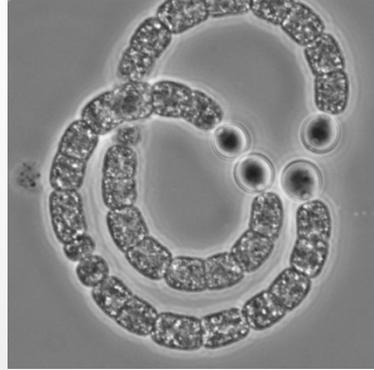
Aphanizomenon at ~800x magnification
Taken with field microscope “Microbescope” at
<http://www.microbescope.com>



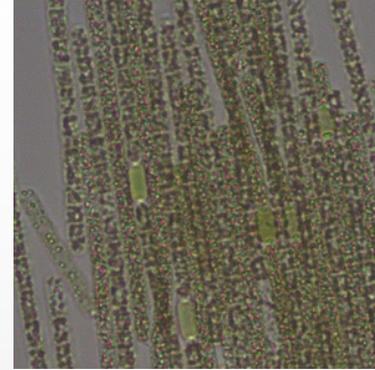
AUTOMATED CLASSIFICATION



Anabaena



Anabaenopsis



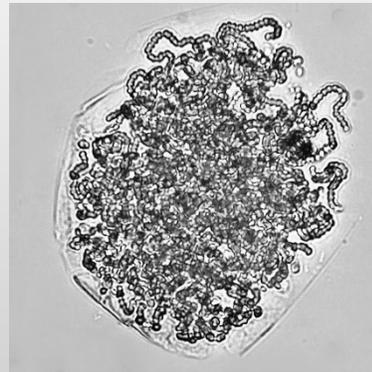
Aphanizomenon



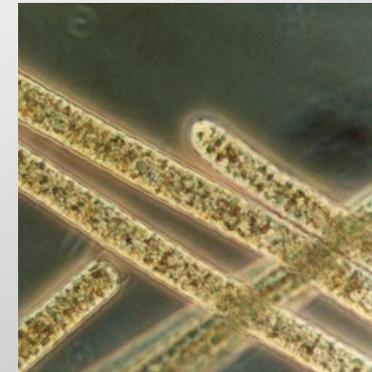
Dolichospermum



Microcystis



Nostoc



Planktothrix

AUTOMATED CLASSIFICATION

- A convolutional neural network was created using Tensorflow to classify seven genera of harmful algae.
- Images were squared, changed to grayscale, and randomly rotated, reflected and translated to artificially augment the training set.
- Results included 53.3% accuracy in prediction of correct class.

VISION

- Artificial neural network using environmental variables (including water color) to provide a water quality index and to predict harmful water quality “events” such as harmful algal blooms
- Smart device application with downloadable models for classification (algae, macroinvertebrates, plankton, fish, other organisms), each using trained neural networks for classification

COLLABORATORS

- Environmental Protection Agency
- Ecological Stewardship Institute at Northern Kentucky University
- Northern Kentucky University Department of Mathematics and Statistics
- Northern Kentucky University Department of Biological Sciences
- Thomas More College Department of Biological Sciences
- Marshall University Department of Biological Sciences
- Ohio River Valley Sanitation Commission (ORSANCO)
- Foundation for Ohio River Education (FORE)
- Oakland University
- Lake Superior State University
- Wayne State University
- Michigan Department of Environmental Quality
- 4DOptical - Microbescope



THANK YOU!

FOR QUESTIONS OR INTEREST IN BETA-TESTING, PLEASE CONTACT ME AT:

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