Drones: A New Tool for Water Monitoring

Donglai Gong

Carl Friedrichs, Ryan Carnegie

VIMS | WILLIAM & MARY

VIRGINIA INSTITUTE OF MARINE SCIENCE

Outline

- What are the goals of water monitoring (from marine scientist's perspective)?
  - Healthy ecosystem? Fisheries / aquaculture? Recreation? (Taste/look/smell)
  - Ability to absorb more anthropogenic input?
- What aspects of water quality can be quantified (via remote sensing)?
  - Physical (sediment load, particulates, clarity, temperature, salinity, color, dissolved gases)
  - Chemical (nutrients, pollutants, pH, DO)
  - Biological (bacteria, phytoplankton, zooplankton, seagrass, macroalgae, fish & shellfish)
- How Chesapeake Bay water quality is currently being monitored.
  - In-situ sampling
  - Satellite remote sensing
  - Numerical Modeling
- What are the limitations of traditional (satellite) remote sensing?
  - Spatial resolution
  - Cloud conditions
  - Low frequency of sampling
- How can drones help with water quality monitoring?
  - Detection & Assessment of Harmful Algal Blooms
  - Rapid response. Local, neighborhood scale information.

What is a healthy Chesapeake Bay ecosystem?

Illustration by Greg Harlin, Wood Ronsaville Harlin, Inc.

What is a healthy Chesapeake Bay ecosystem?

2016 Eco Health Report Card

https://ecoreportcard.org/report-cards/chesapeake-bay/health/
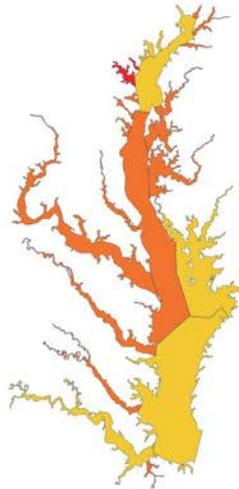
What is a healthy Chesapeake Bay ecosystem?

2011 Eco Health Report Card

https://ecoreportcard.org/report-cards/chesapeake-bay/health/
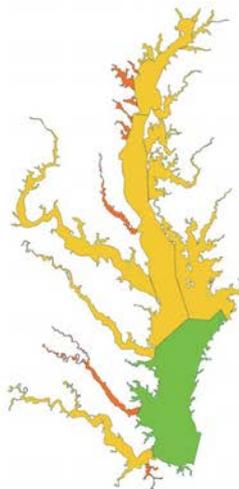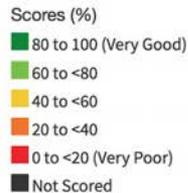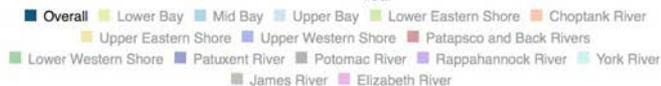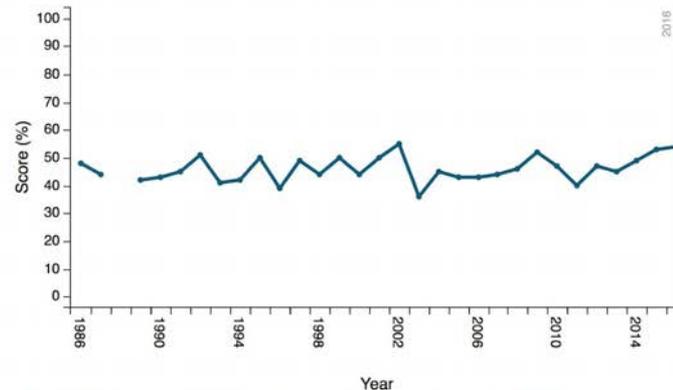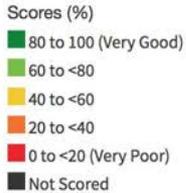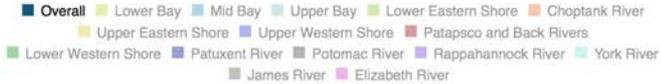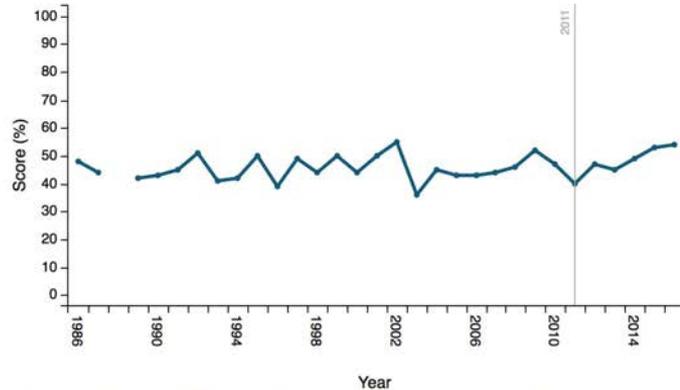
Attenuation (via K_d) and transparency (via Secchi depth) measure different light properties

- Downwelling light.
- Full range from 400 to 700 nm.
- Less sensitive to light path.
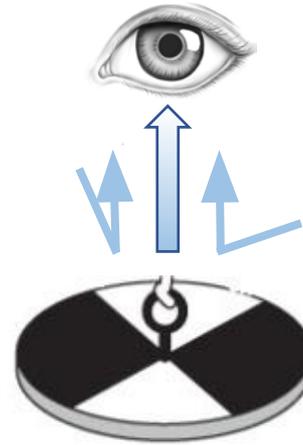
- Reflected light.
- Most sensitive to 555 nm.
- Light must return on direct path to eye.
- More sensitive to light scattering.

LiCor Quantum Sensor Sensitivity Curve (PAR)
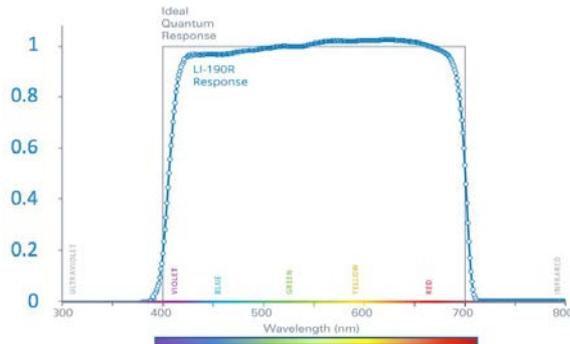
Spectral Sensitivity of Human Eye

Photopic (light-adapted) max = 555 nm

Relative Response Log Scale

Relative Response Non-Log Scale
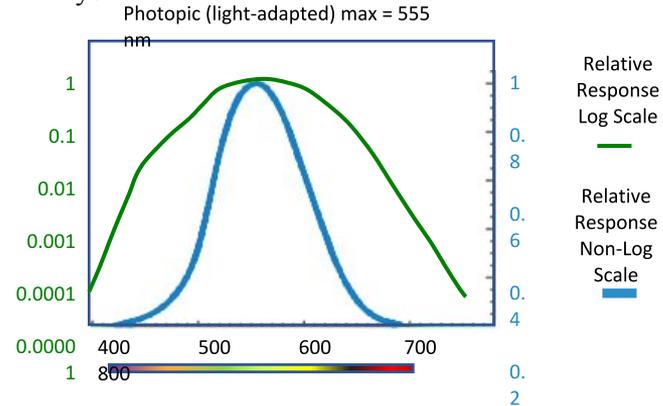
(Graphics courtesy of C. Buchannan, pers. comm.)

According to optical models, we expect tour main factors to contribute to scattering and absorption of light in Bay waters:
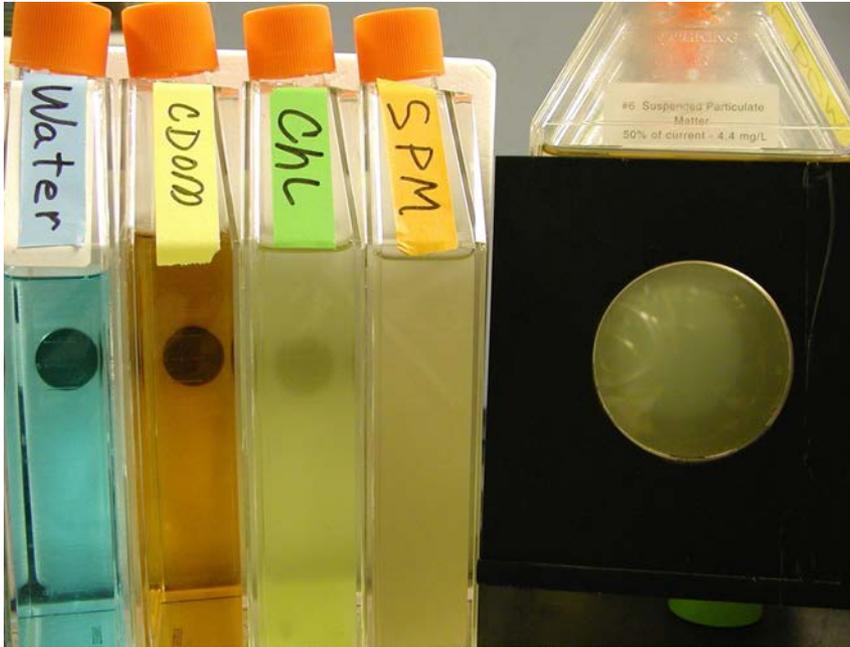
1. Water
2. Colored dissolved organic matter
3. Chlorophyll
4. Suspended particulate matter (a.k.a., Total Suspended Solids)

(Gallegos 2005)

Trends in Secchi Depth, 1960 - 2016
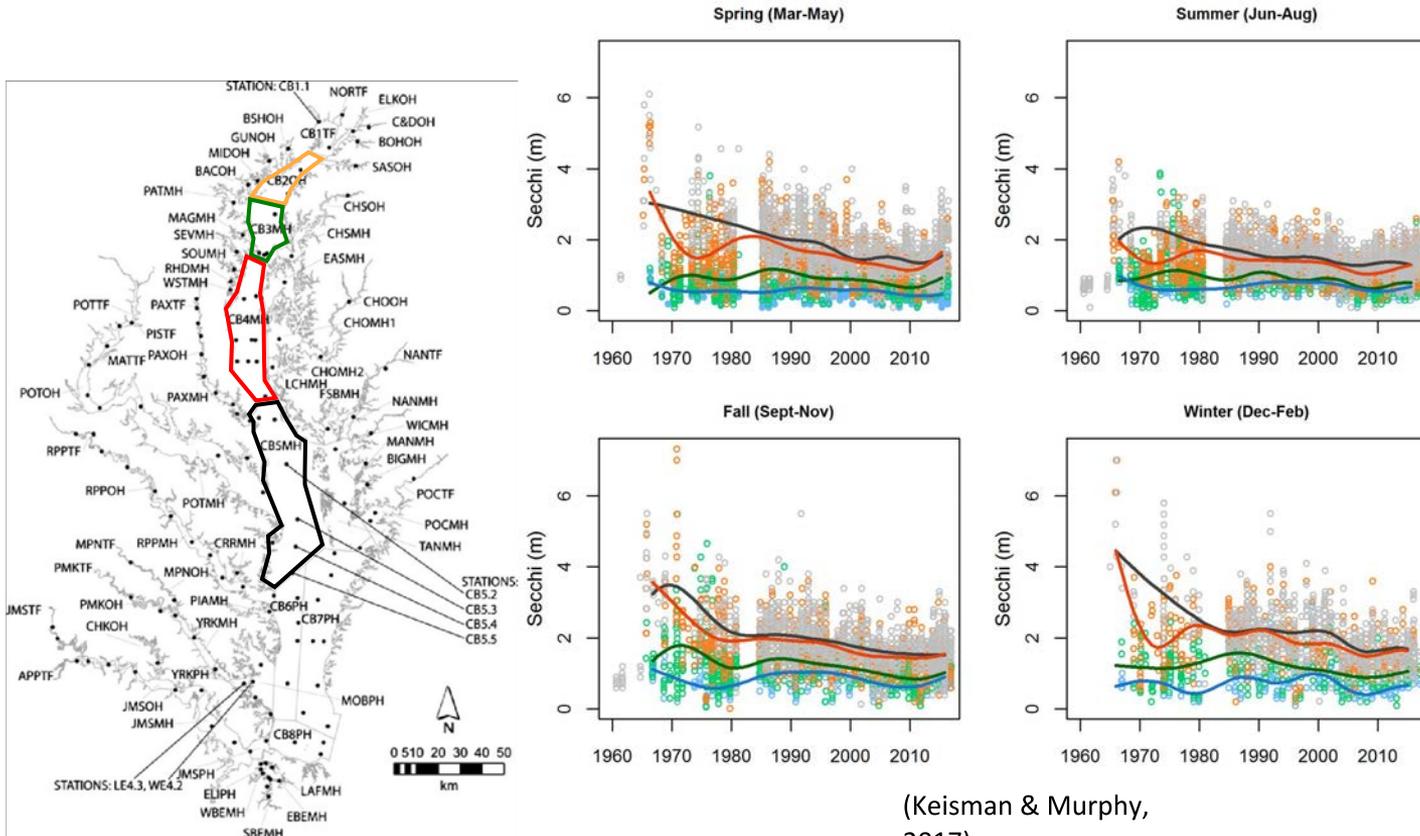
(Williams et al. 2010)

(Keisman & Murphy, 2017)

Apr-Oct: Trends for surface Chlorophyll-a in ~10 years from mid-1990s to mid-2000s
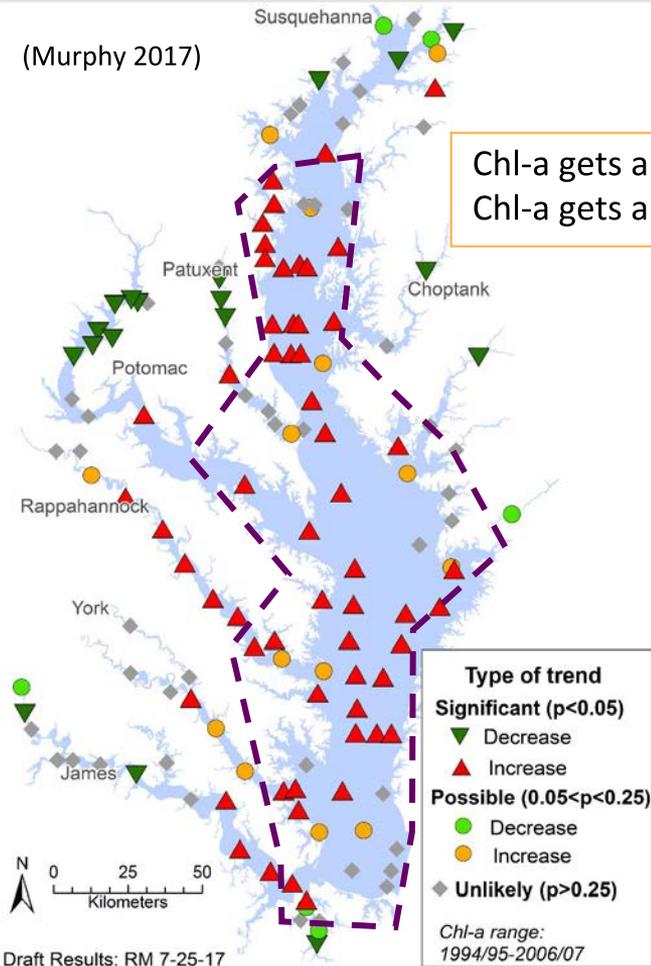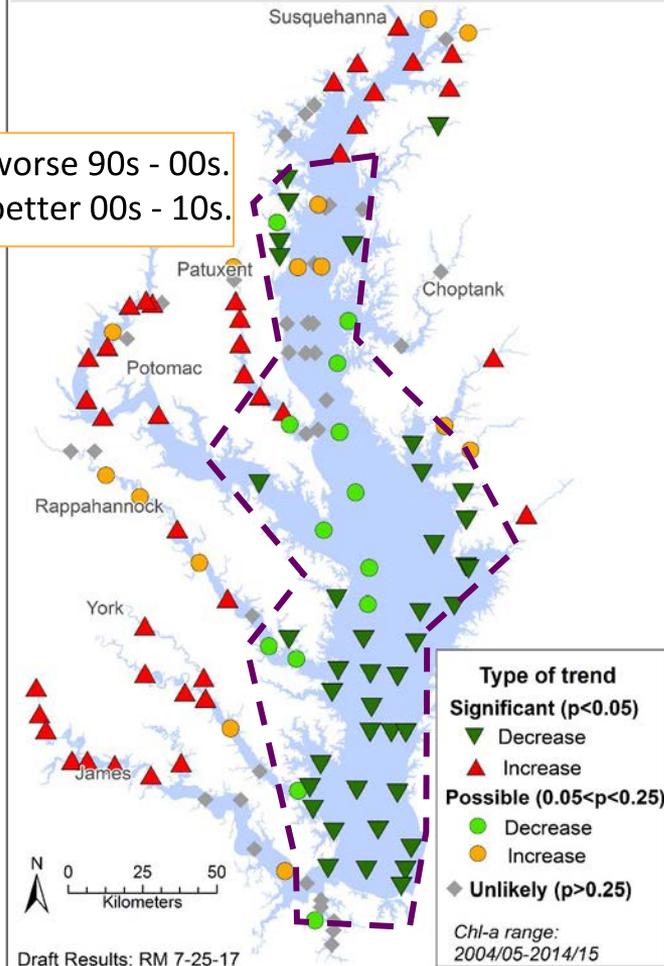
(Murphy 2017)

Chl-a gets a lot worse 90s - 00s.
Chl-a gets a lot better 00s - 10s.

Type of trend
Significant (p<0.05)
▼ Decrease
▲ Increase
Possible (0.05<p<0.25)
● Decrease
● Increase
◆ Unlikely (p>0.25)

Chl-a range: 1994/95-2006/07

Draft Results: RM 7-25-17

Apr-Oct: Trends for surface Chlorophyll-a in ~10 years from mid-2000s to mid-2010s

Type of trend
Significant (p<0.05)
▼ Decrease
▲ Increase
Possible (0.05<p<0.25)
● Decrease
● Increase
◆ Unlikely (p>0.25)

Chl-a range: 2004/05-2014/15

Draft Results: RM 7-25-17

Apr-Oct: Trends for Secchi where sampled in ~10 years from mid-1990s to mid-2000s

(Murphy 2017)

Z_{SD} gets a lot worse 90s - 00s.
Z_{SD} gets a lot better 00s - 10s.

Susquehanna
Patuxent
Choptank
Potomac
Rappahannock
York
James

Type of trend
Significant (p<0.05)
▼ Decrease
▲ Increase
Possible (0.05<p<0.25)
● Decrease
● Increase
◆ Unlikely (p>0.25)

Draft Results: RM 4-28-17

Most frequent range: 1994/95 - 2006/07
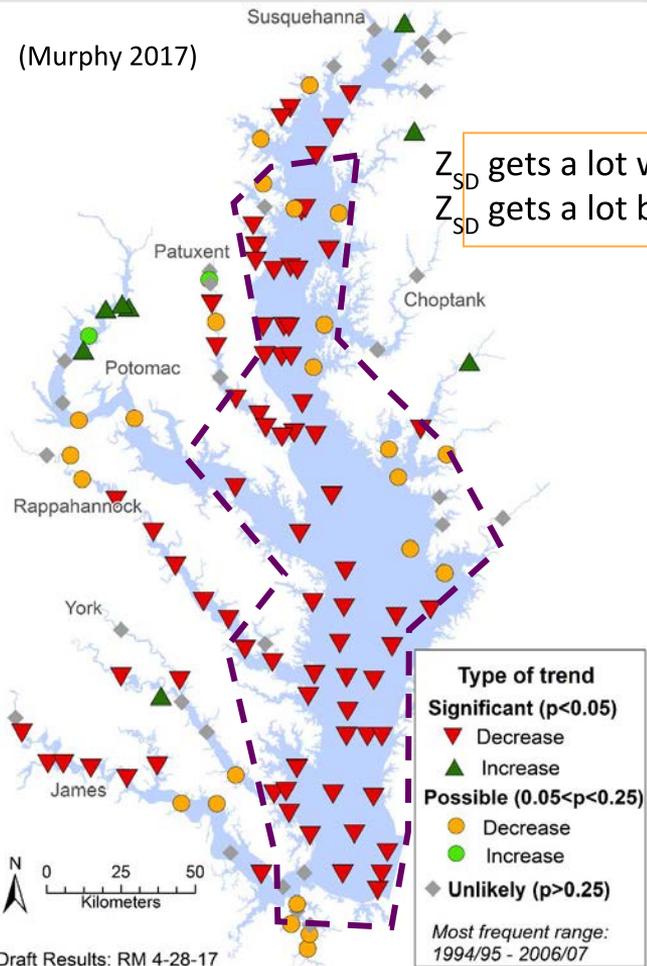
Apr-Oct: Trends for Secchi where sampled in recent ~10 years from mid-2000s to mid-2010s
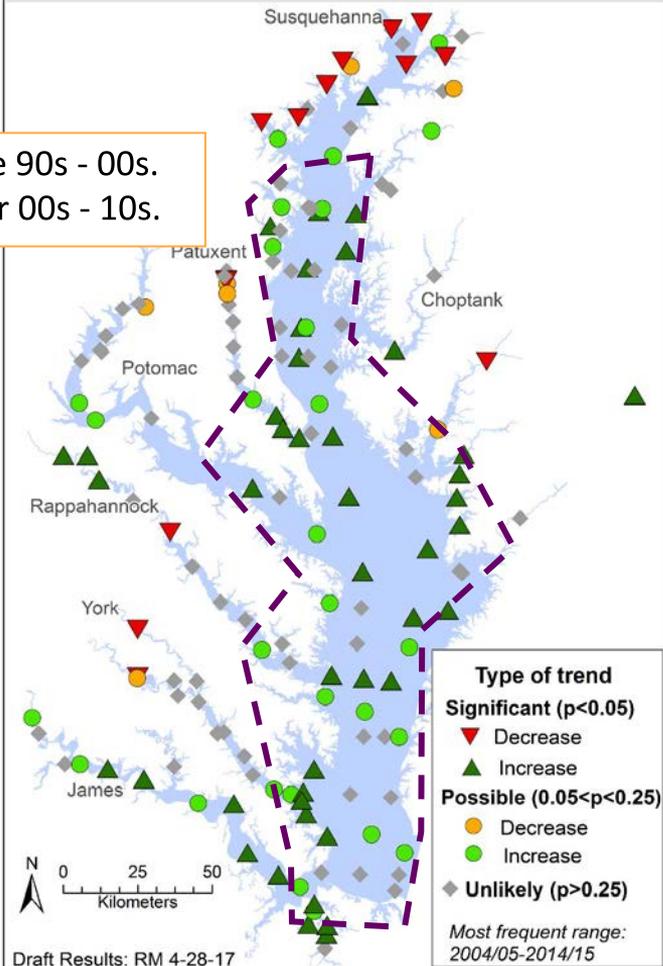
Susquehanna
Patuxent
Choptank
Potomac
Rappahannock
York
James

Type of trend
Significant (p<0.05)
▼ Decrease
▲ Increase
Possible (0.05<p<0.25)
● Decrease
● Increase
◆ Unlikely (p>0.25)

Draft Results: RM 4-28-17

Most frequent range: 2004/05-2014/15

Satellite remote sensing of water quality in the CBay

True Color (7/30/17)
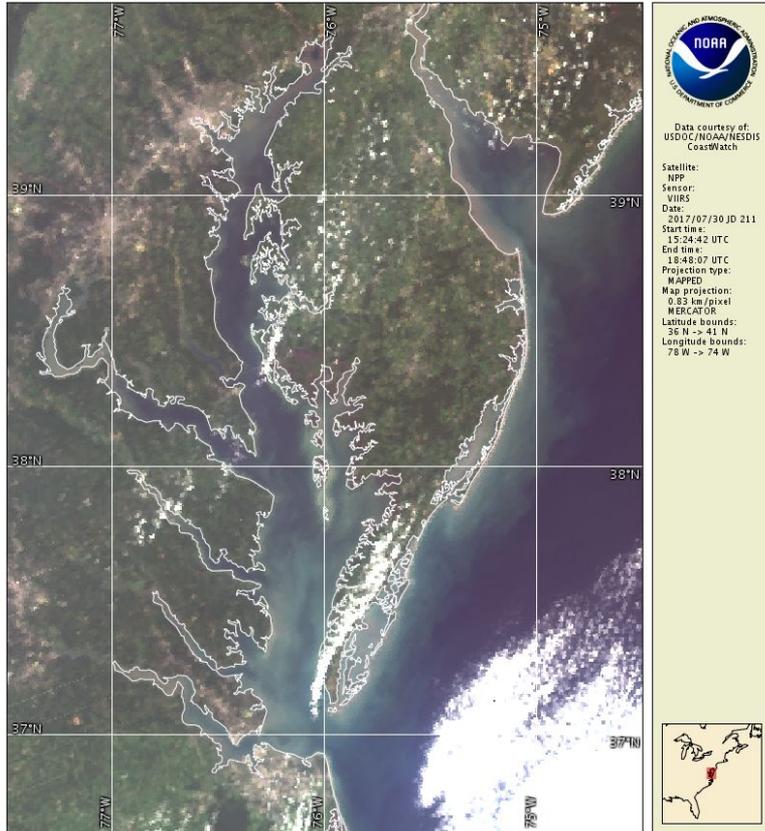
Chlorophyll-a

Satellite remote sensing of water quality in the CBay

Total Suspended Matter (7/30/17)

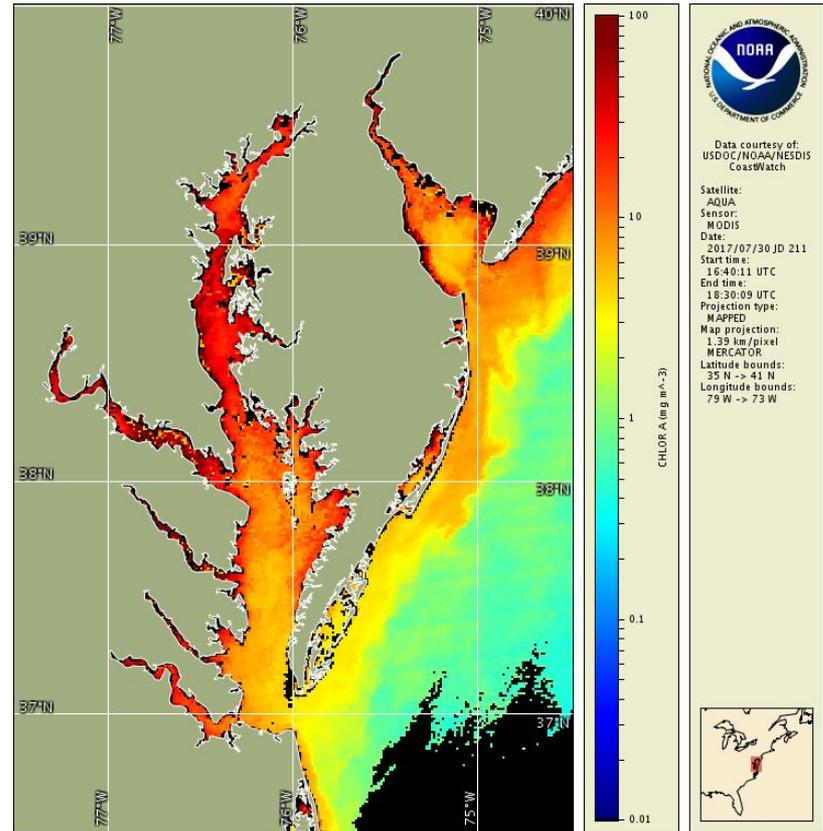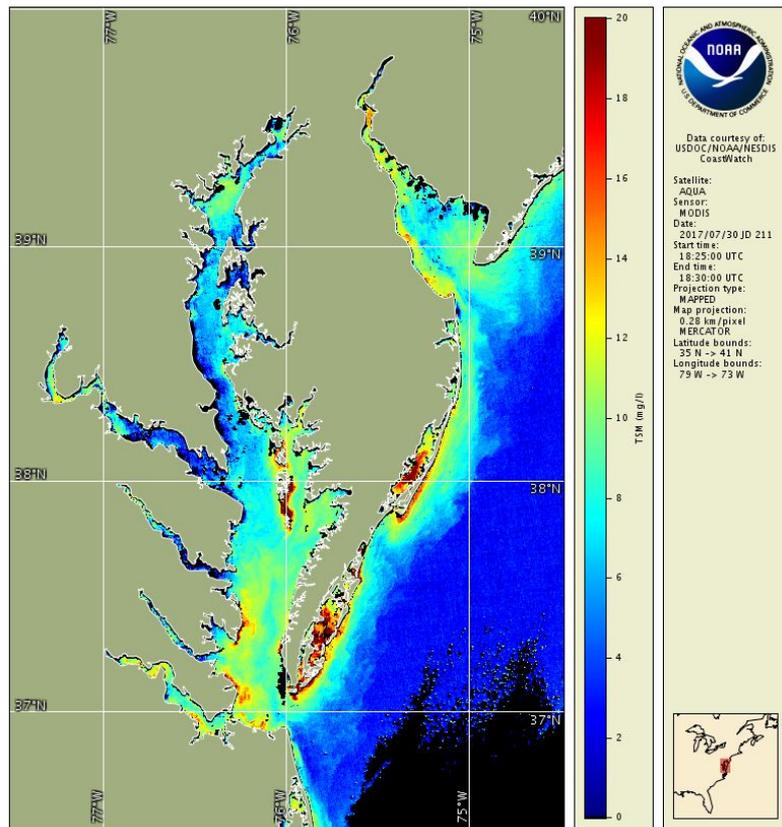Diffuse Attenuation at 490nm
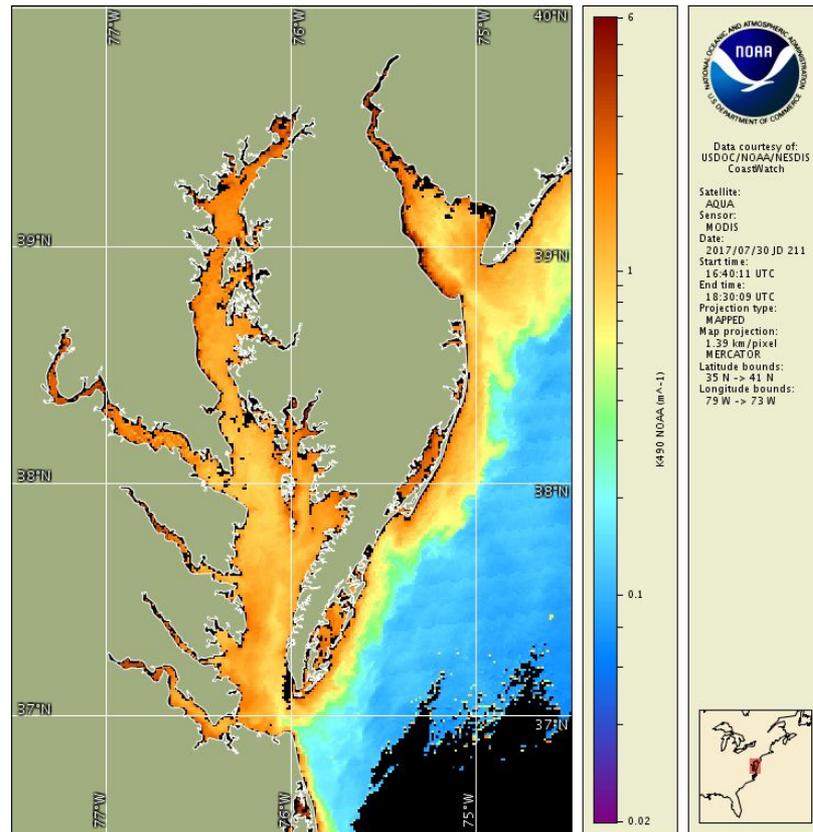
Limitations of satellite remote sensing for CBay monitoring

- Good for physical and some biological water quality parameters.
- Great for bay-scale and seasonal scale view and comparisons.
- Coarse Resolution ~ 0.3 - 1 km
  - Most smaller tributaries are less than 300 m wide.
  - Features within tributaries are on even smaller scale (10 - 200 m).
  - Bad data at a few pixels can affect the measurement for the entire tributary.
  - There is no resampling.
- Satellite ocean color data are strongly affected by cloud and fog. Sometimes, data availability for a whole month is less than 50%.
- Sampling frequency: once per day
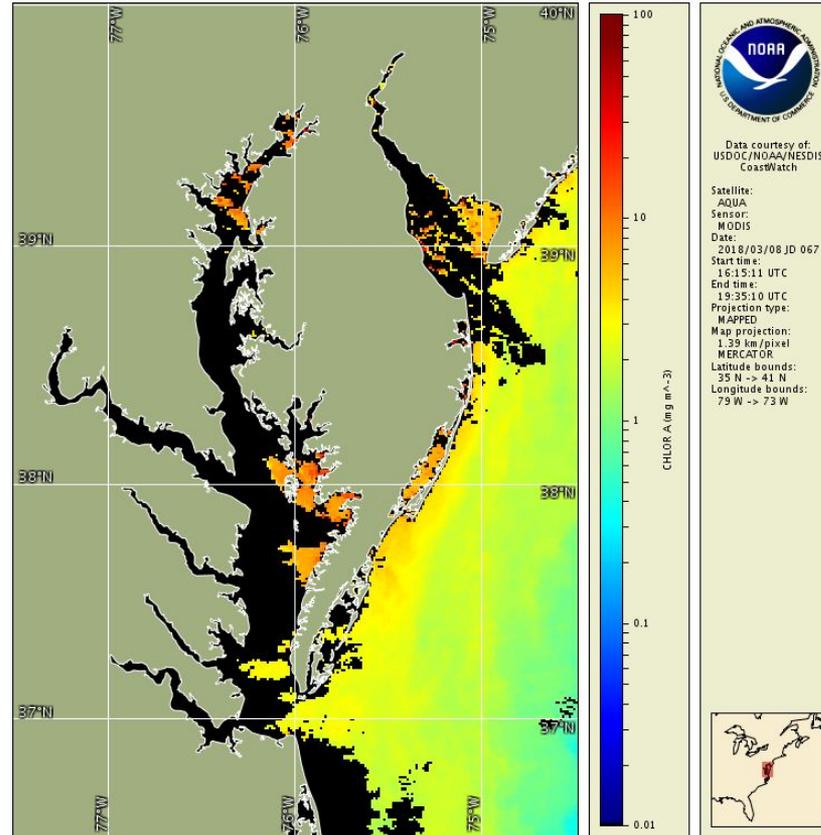
New generation of multspectral satellites can achieve 10 m resolution: ESA Sentinel 2
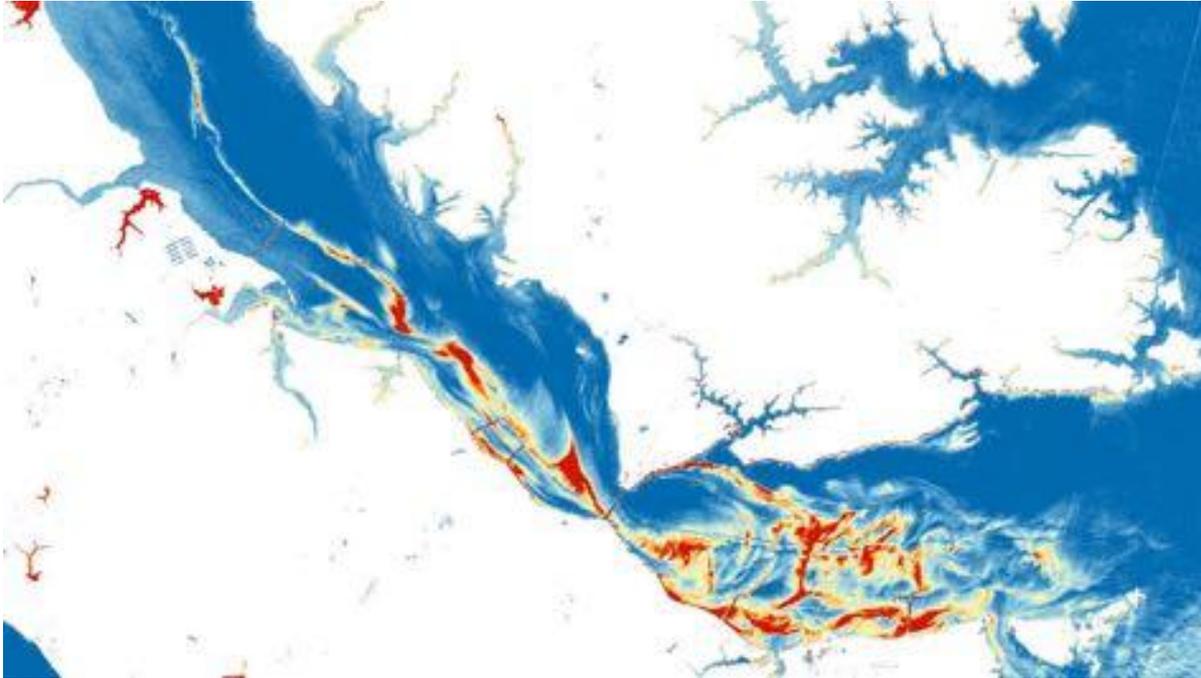
1 pass every 10 days

Still affected by clouds

http://www.vims.edu/newsandevents/topstories/2016/hab_partners.php

How can drones help with CBay water quality monitoring?

- Extremely high resolution data (few cm to 100 m).
- Enable tributary and neighborhood scale water quality monitoring.
- Rapid response to environmental changes (multiple samples per day)
- VIDEO & timelapse!!!
- Much less sensitive to cloud, just need sufficient light.
- Low equipment and logistics cost.
- Citizen science possible!
- Large quantities of data.
- Not for bay-scale sampling.
- Restricted by airspace regulations.
- Advanced sensors are expensive.
- Data quality control is hard and data processing is not uniform.
- Ground truthing & georeferencing is nontrivial and can be expensive.

Harmful Algal Bloom near Catlett Island

Major types of drones: fixed-wing

Parrot Disco

AeroVironment Quantix

Fixed-wing drones were the first to be developed. Traditionally they have longer endurance and range. May require launch system & large operating area. Mostly military users, civil uses on the rise, particularly in agriculture and land survey.

Major types of drones: Multi-rotor (e.g. quadcopter)

Parrot
Bebop

DJI Phantom 4
Pro

DJI Matrice
600

- **By far the most popular type of recreational and commercial drone ($500 - $5000)**

- **Easy to control & fly, vertical take off and landing**

- **High quality HD/4K photos and videos**

- **1-3 miles range, speed 15-25 mph.**

Drone Applications in Marine Science: Brief history at VIMS

- Center for Coastal Resource Management first acquired a drone in 2013 for shoreline surveys

- Coastal & Polar Phys. Oceanography lab started marine drone operations in 2014

- Coastal Geomorphology & Ecology Lab started using drones to study marsh evolution in 2015

- First graduate drone operations & applications course offered at VIMS in spring 2017

- Eastern Shore Lab started using drone to study marsh grass die off in 2017

- Multiple labs collaborated in summer 2017 using drone and vessel-based surveys to study Harmful Algal Blooms

Drone Monitoring of Seagrass Health

- Sea grass beds are important nursery grounds for many species of marine organisms in the Chesapeake Bay.

- Their location, thickness, and distribution can change significantly from weeks to months.

- VIMS scientists have been studying and monitoring them for a long time.

- Drone would allow us to study seagrass at unprecedented high resolution and time scale. Event scale changes for the whole bed can be studied at low cost.

Drone Monitoring of Seagrass Health

Seagrass are beautiful and they serve as nursery for fish larvae. Drone will supplement traditional sampling to help monitor their response to environmental change in the bay.

Drone Study of Harmful Algal Blooms (HABs)


- HABs have become a common summer time phenomenon in the Chesapeake Bay

- The problem has worsened in the past decade yet the drivers of HAB events in the Chesapeake Bay is largely unknown.

- HABs can vary on hourly time scale with fine scale features on the scale of meter or less.

- Physics vs. biology, which is driving the variability?

http://www.vims.edu/bayinfo/habs/index.php

What are HABs?

Cochlodinium polykrikoides

Alexandrium monilatum
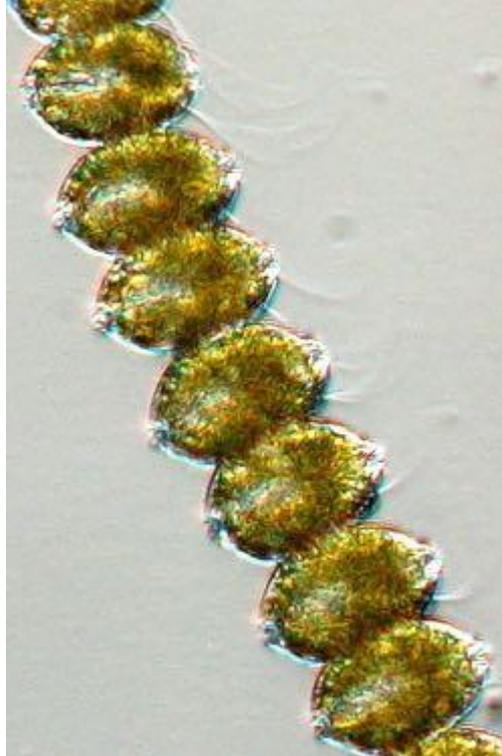
- Two of the dominant HAB species in the Chesapeake Bay are Cochlodinium and Alexandrium, both are dinophlagellates.

- Cochlodinium typically blooms first in the summer (July - August).

- Alexandrium blooms after Cochlodinium and bioluminesce at night (August - September).

- The physical and biological drivers of their life phases are largely not well known.

Drone Study of Harmful Algal Blooms

- Aerial drone imagery allow scientists to capture structures and patterns in HABs that cannot be easily captured otherwise.

- The images tell us that HAB distribution is very dependent on tidal circulation and mixing.

- HABs hotspots are often found in shallow enbayments and can bloom in matter of days after a mixing event.

- Next step is to identify the types of organisms in the water from drone images. Require new multispectral sensors.

Drone Study of Harmful Algal Blooms

Drone Study of Harmful Algal Blooms

- HAB can vary on very short time scales – hours

- Spatial scale on meters to hundreds of meters

- York River has been a hotspot of HAB in the CBay

- Using York River as a testbed for developing HAB monitoring tools including drone technology that will be applicable to other parts of CBay.

Drone Study of Harmful Algal Blooms

Ground truth with in-situ water sampling

Collaboration between physical, chemical, and biological marine scientists.

Part of NSF-funded study.

Drone Study of Harmful Algal Blooms

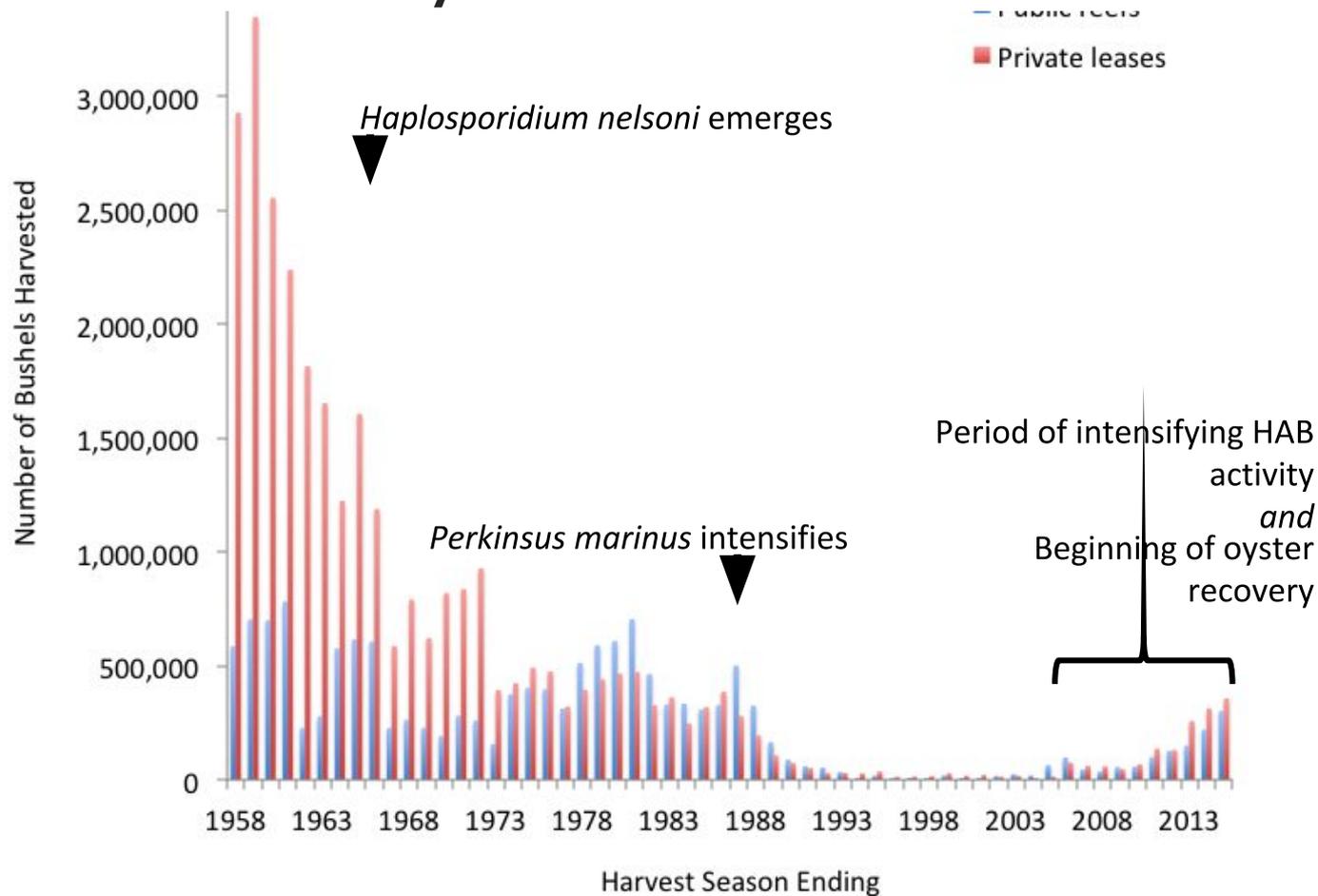# Drone Study of Harmful Algal Bloom and other things in water:

Drone Study of Harmful Algal Blooms
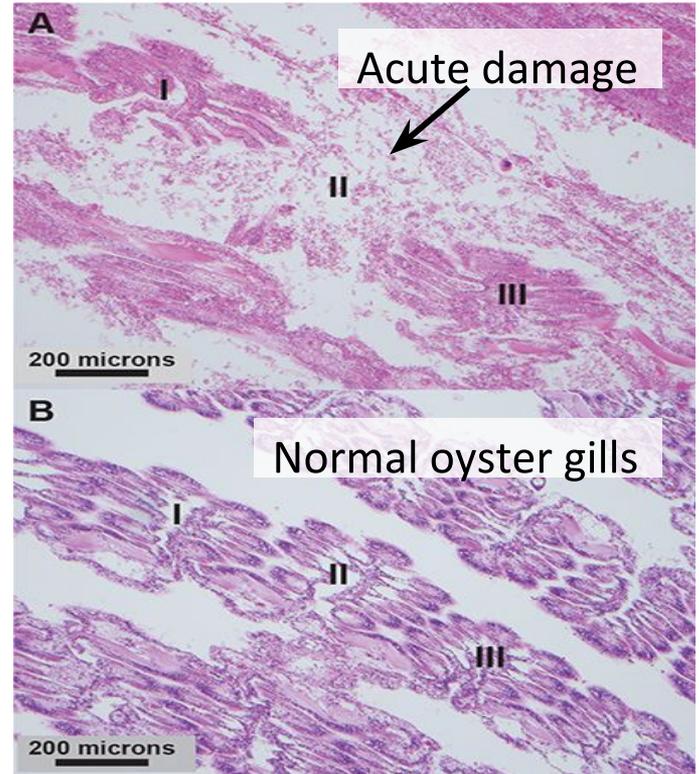
Drone Study of Harmful Algal Blooms

Oysters and HABs

Oysters and HABs

❖ Lab exposure to *Alexandrium monilatum* can cause damage to oyster tissues (see figure)

❖ Bloom-associated hypoxia an additional threat

❖ In natural systems, no clear signs of HAB-associated disease and mortality

❖ Recovery of oyster populations, in fact, corresponds to period of increasing bloom activity

❖ Oysters resilient in the face of blooms

Acute damage

Normal oyster gills

Summary:

- Drone technology enables effective monitoring of small tributary and neighborhood scale water bodies.
- Applications includes seagrass, harmful algal blooms, and oil spill events.
- Excel in high resolution and event scale rapid response.
- Challenges remain in data georeferencing, processing, calibration, & sharing.
- Precision georeferencing & advanced sensors such as multispectral and hyperspectral imagers will drive future quantitive applications.
- Drone is an excellent platform to potentially engage the public in citizen science.

Thank You!