# COLLABORATIVE SCIENCE FOR ESTUARIES
WEBINAR SERIES

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*Guana Tolomato Matanzas (GTM) NERR*

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*North Inlet-Winyah Bay NERR*

**Hannah Ramage**
*Lake Superior NERR*

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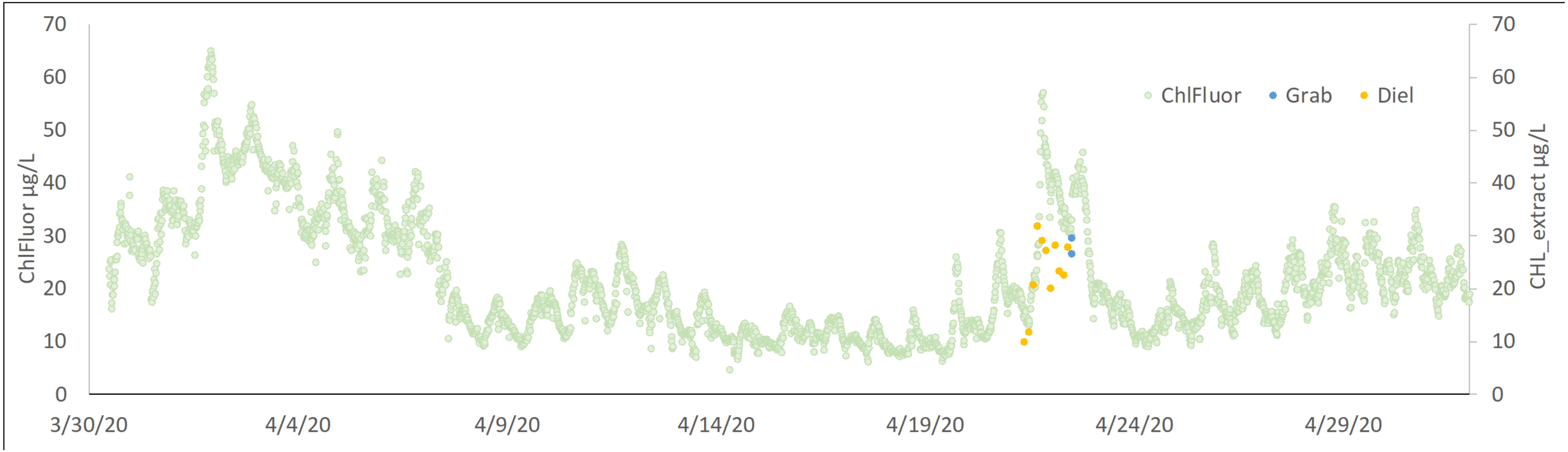
# Refining Techniques for High-Frequency Monitoring of Chlorophyll

National Estuarine
Research Reserve System
Science Collaborative

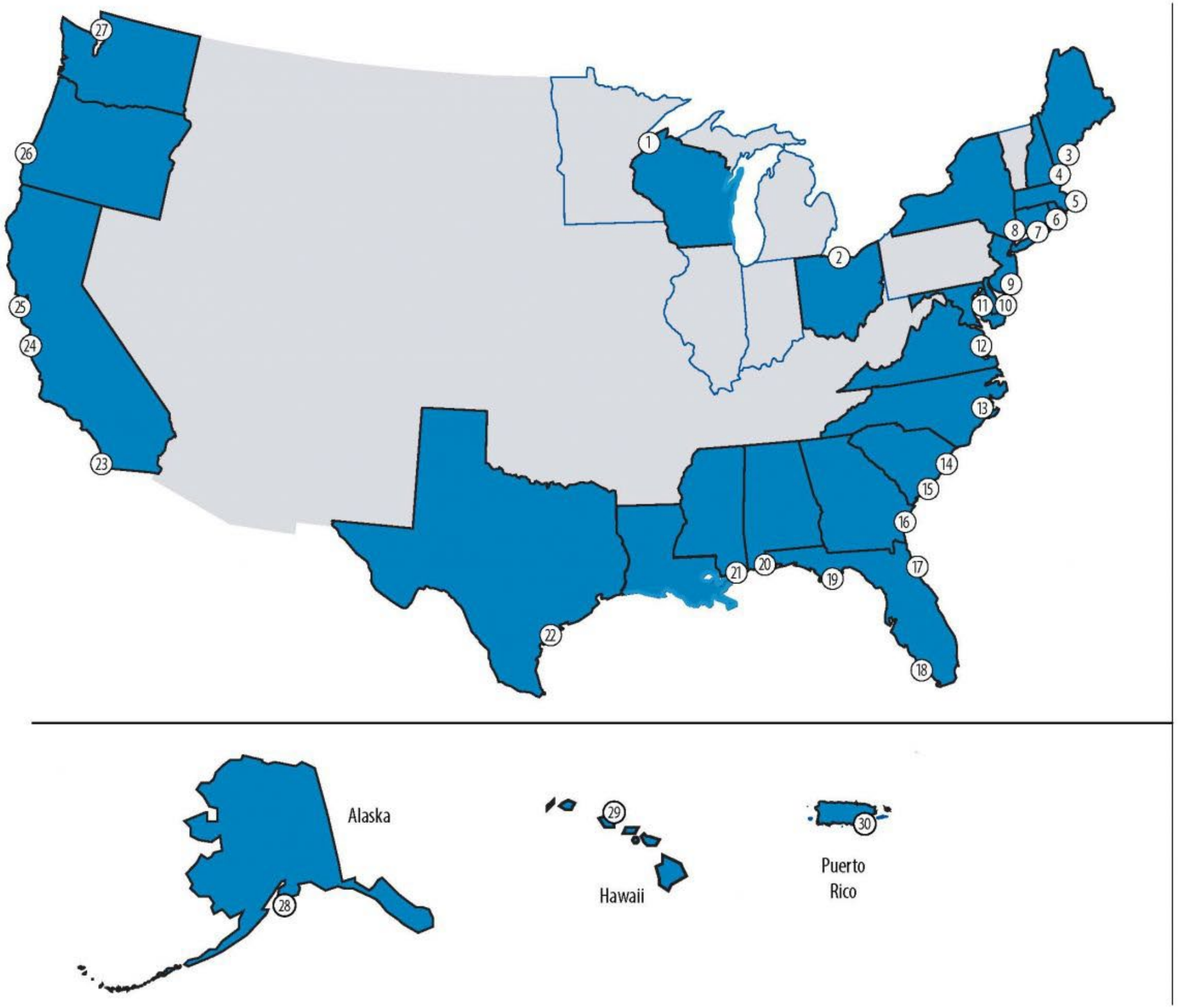
Date: Tuesday, April 19, 2022
Time: 3:30-4:30 PM ET

# Refining techniques for high-frequency monitoring of chlorophyll *a* in the National Estuarine Research Reserve System

Nikki Dix, Erik Smith, Silas Tanner, Shannon Dunnigan, Hannah Ramage, Kim Cressman, Steven McMurray, Jacob Cianci-Gaskill, Rikke Jeppesen, Yoshimi Rii, Rachel Guy, Cammie Hyatt, Nicole Burnett, Cassie Porter, Jeremy Miller, Tom Gregory, Silvia Yang, Thompson Rose, Kelley Savage, Sebastian Mejia



# NATIONAL ESTUARINE RESEARCH RESERVES




Great Lakes
1. Lake Superior, Wisconsin
2. Old Woman Creek, Ohio

Northeast
3. Wells, Maine
4. Great Bay, New Hampshire
5. Waquoit Bay, Massachusetts
6. Narragansett Bay, Rhode Island
7. Connecticut

Mid-Atlantic
8. Hudson River, New York
9. Jacques Cousteau, New Jersey
10. Delaware
11. Chesapeake Bay, Maryland
12. Chesapeake Bay, Virginia

Southeast
13. North Carolina
14. North Inlet-Winyah Bay, South Carolina
15. ACE Basin, South Carolina
16. Sapelo Island, Georgia
17. Guana Tolomato Matanzas, Florida

Gulf of Mexico
18. Rookery Bay, Florida
19. Apalachicola, Florida
20. Weeks Bay, Alabama
21. Grand Bay, Mississippi
22. Mission-Aransas, Texas

West
23. Tijuana River, California
24. Elkhorn Slough, California
25. San Francisco Bay, California
26. South Slough, Oregon
27. Padilla Bay, Washington
28. Kachemak Bay, Alaska

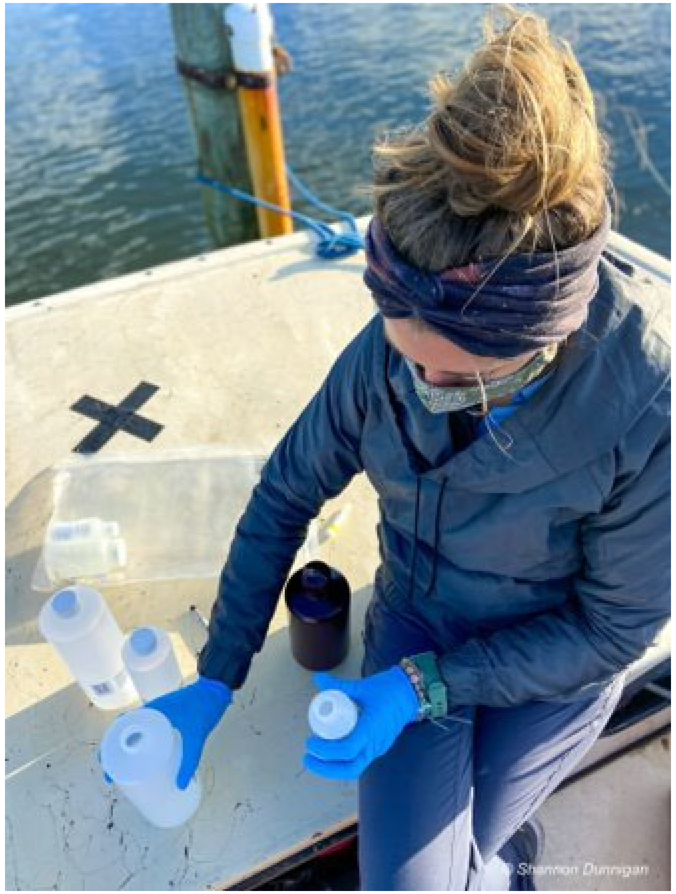
Pacific
29. He'eia, Hawai'i

Caribbean
30. Jobos Bay, Puerto Rico

**PROPOSED**

Bay of Green Bay, Wisconsin
Louisiana

# System-Wide Monitoring Program


# Chlorophyll *a*

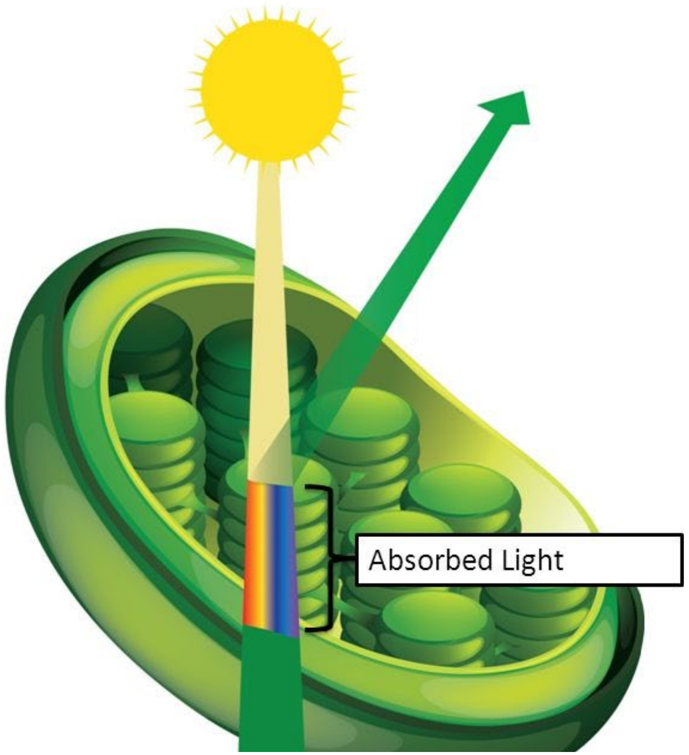
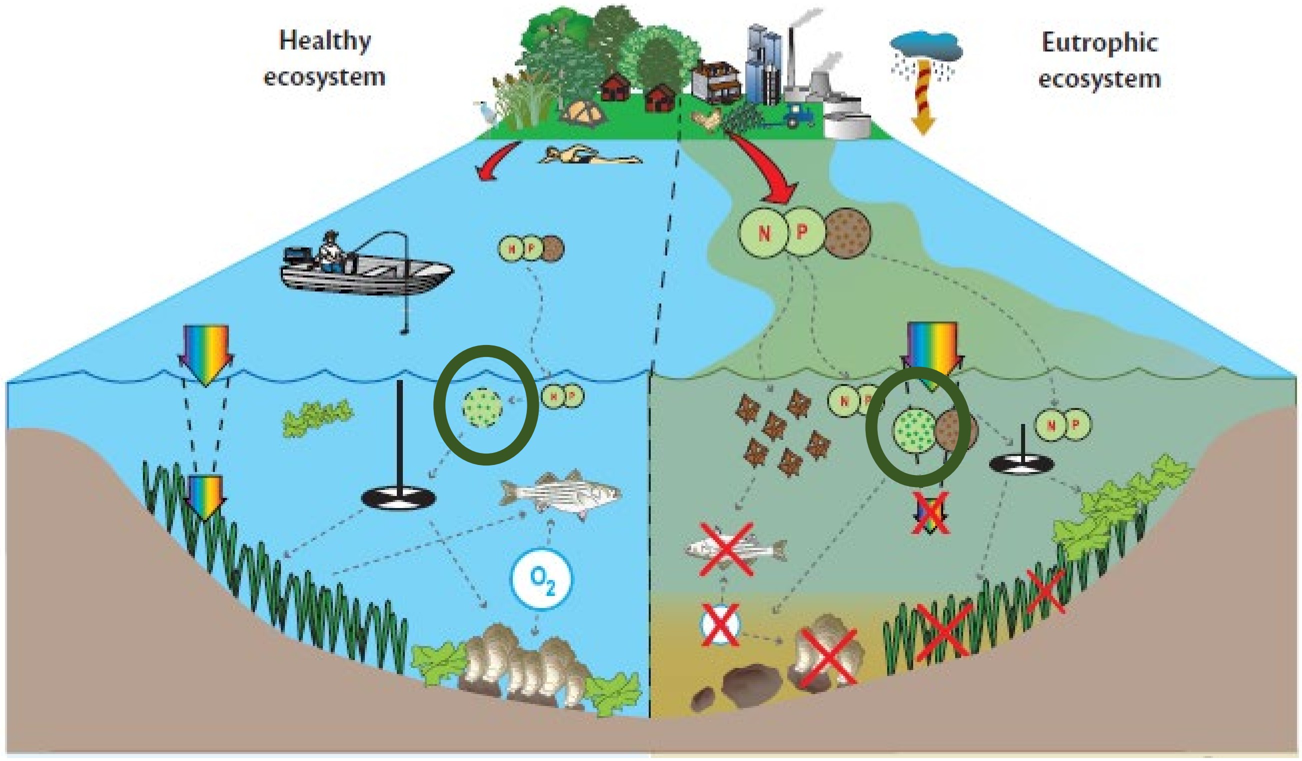


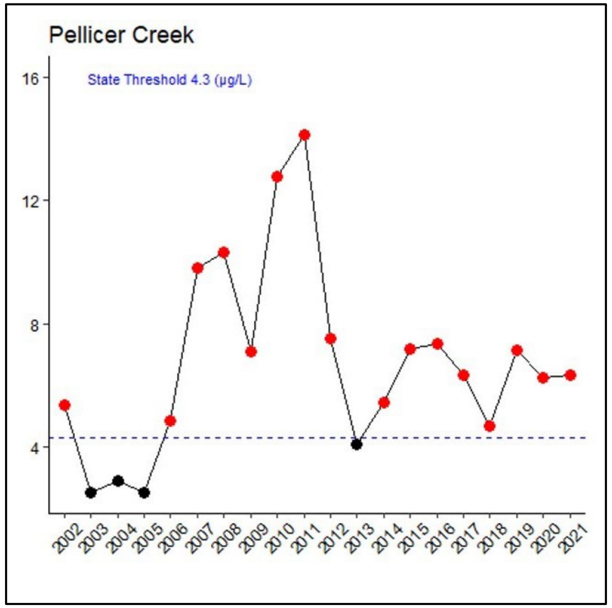

Image credit: https://slideplayer.com/slide/3922722/

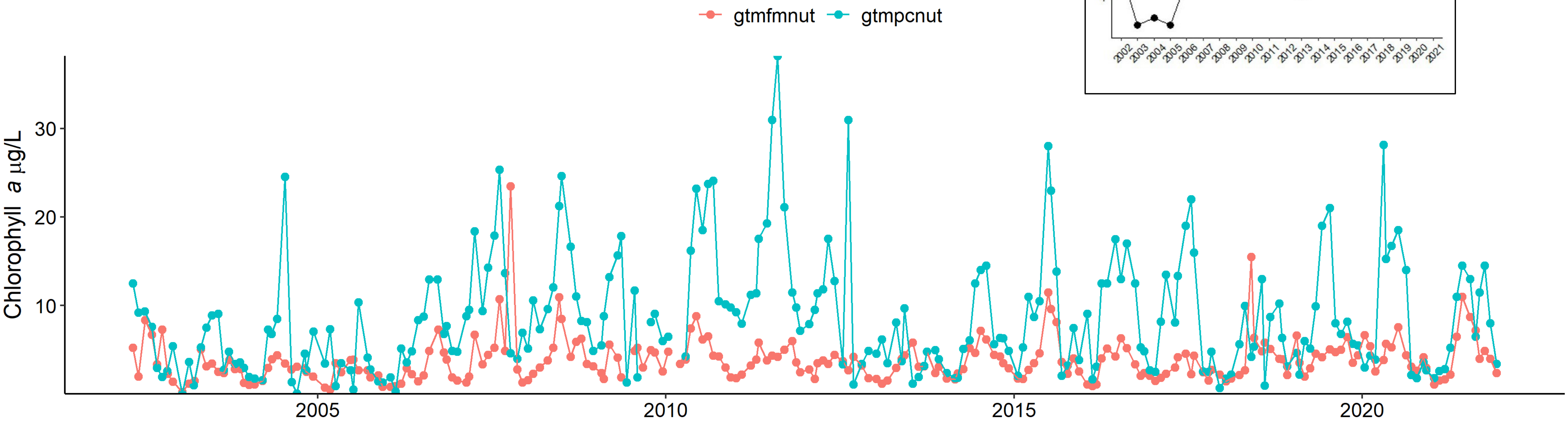



Bricker et al. 2007. Effects of Nutrient Enrichment In the Nation's Estuaries: A Decade of Change. NOAA Coastal Ocean Program Decision Analysis Series No. 26. National Centers for Coastal Ocean Science, Silver Spring, MD. 328 pp.

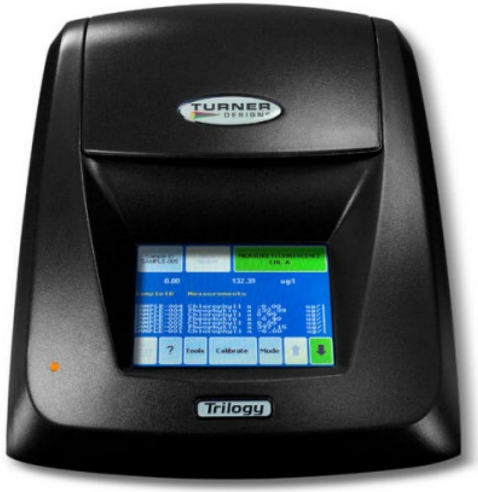
# Monthly Discrete Monitoring

Valuable for
- Long-term trends
- Seasonality
- Trophic status



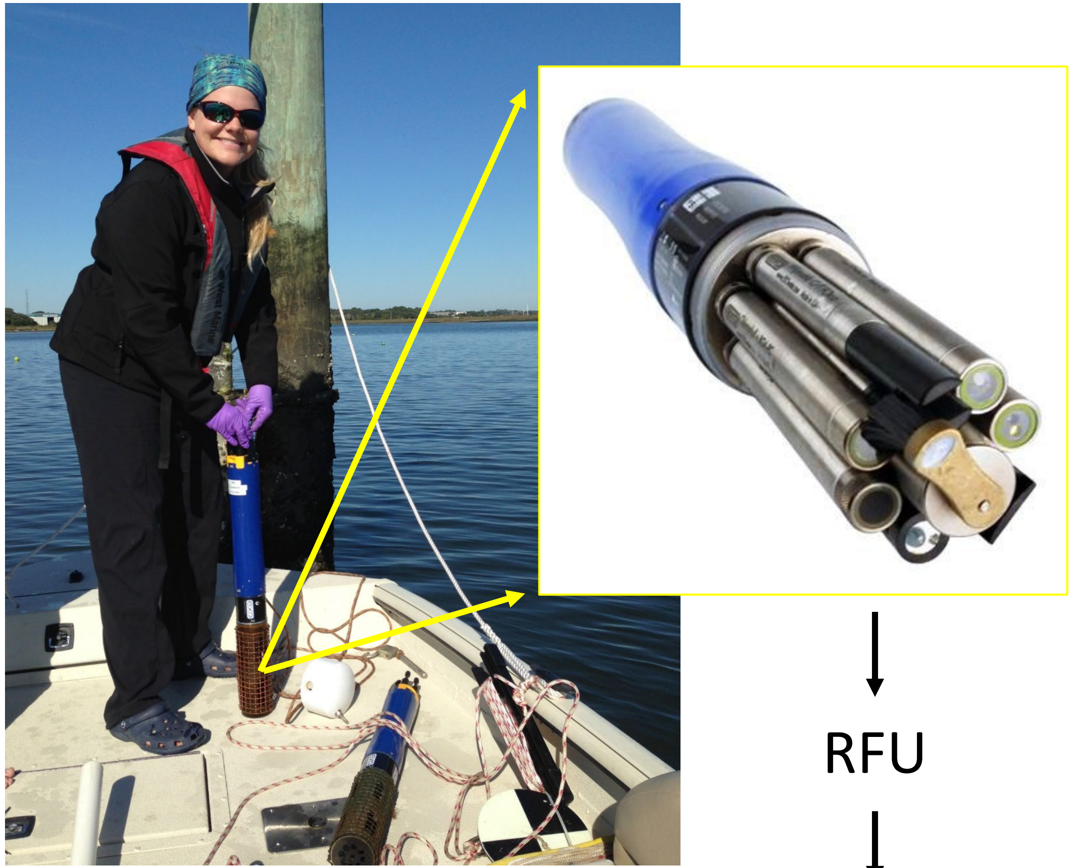
# Extracted Chlorophyll *a*


↓

µg/L

# *In situ* chlorophyll *a*



RFU

µg/L

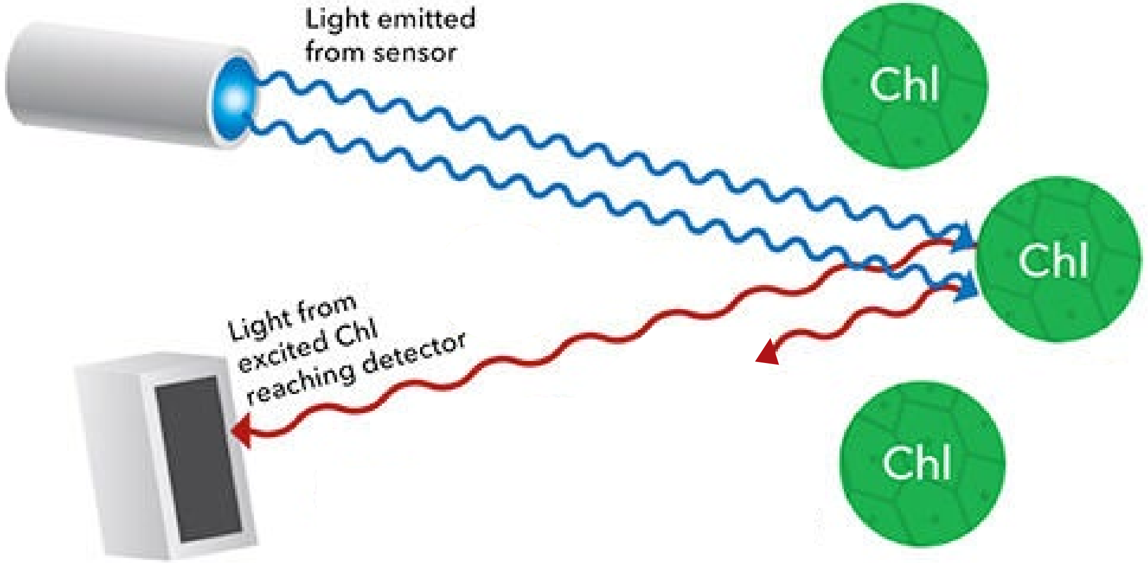
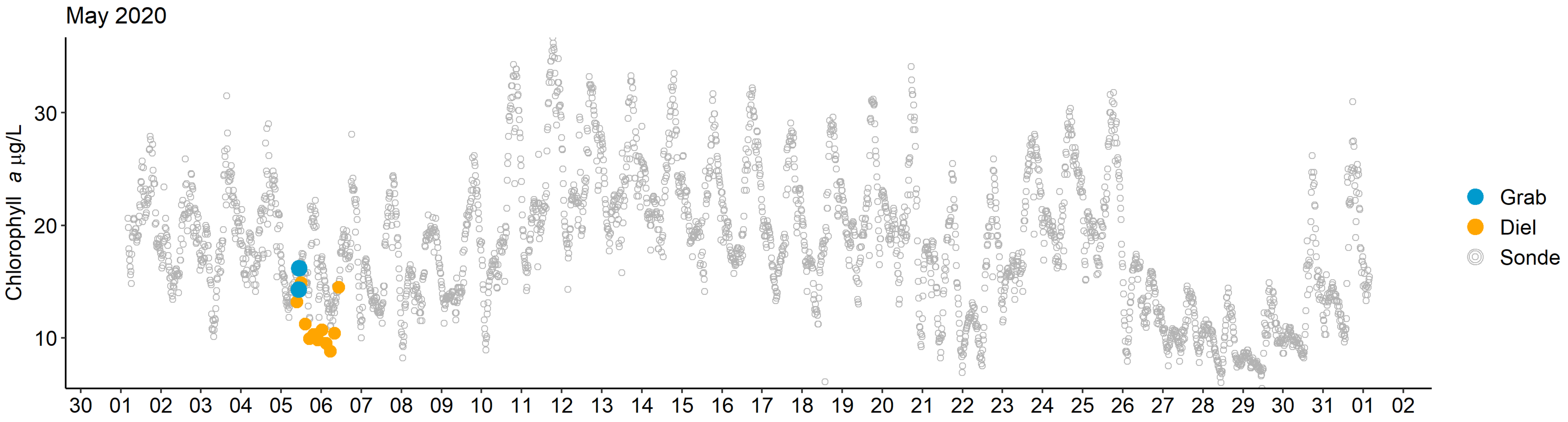



Image credit: www.ysi.com

# *In situ* chlorophyll *a*

Valuable for

- Short-term plankton dynamics
  - Light, tides, flow, storms, etc.
- Bloom detection



# *In situ* chlorophyll *a*

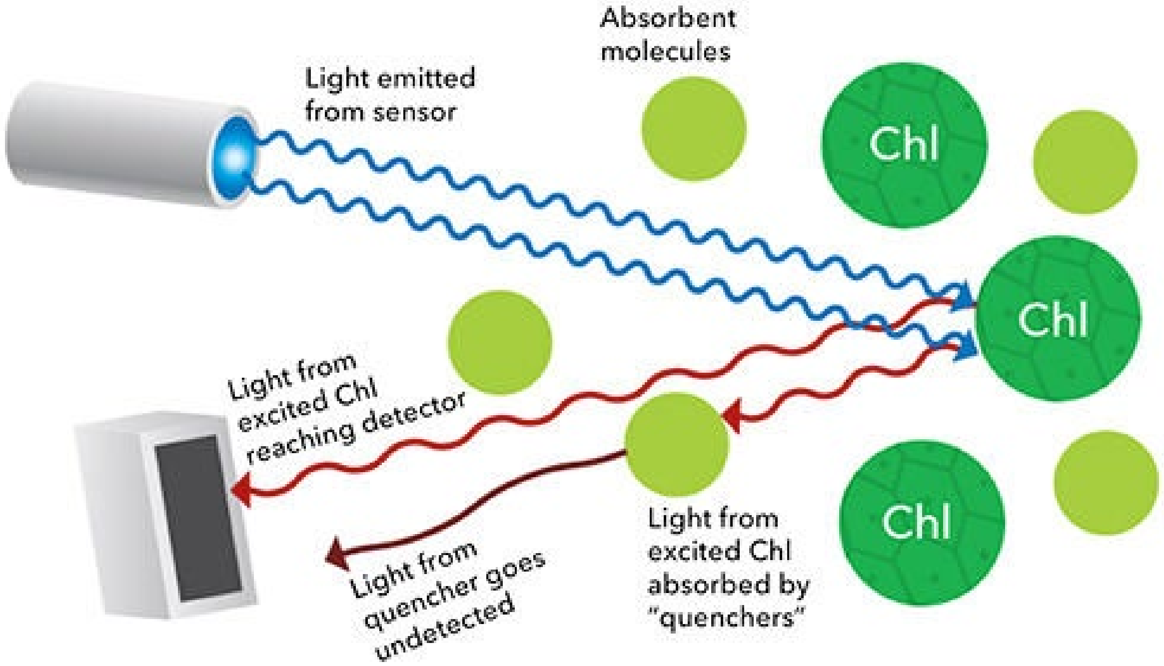



Image credit: www.ysi.com

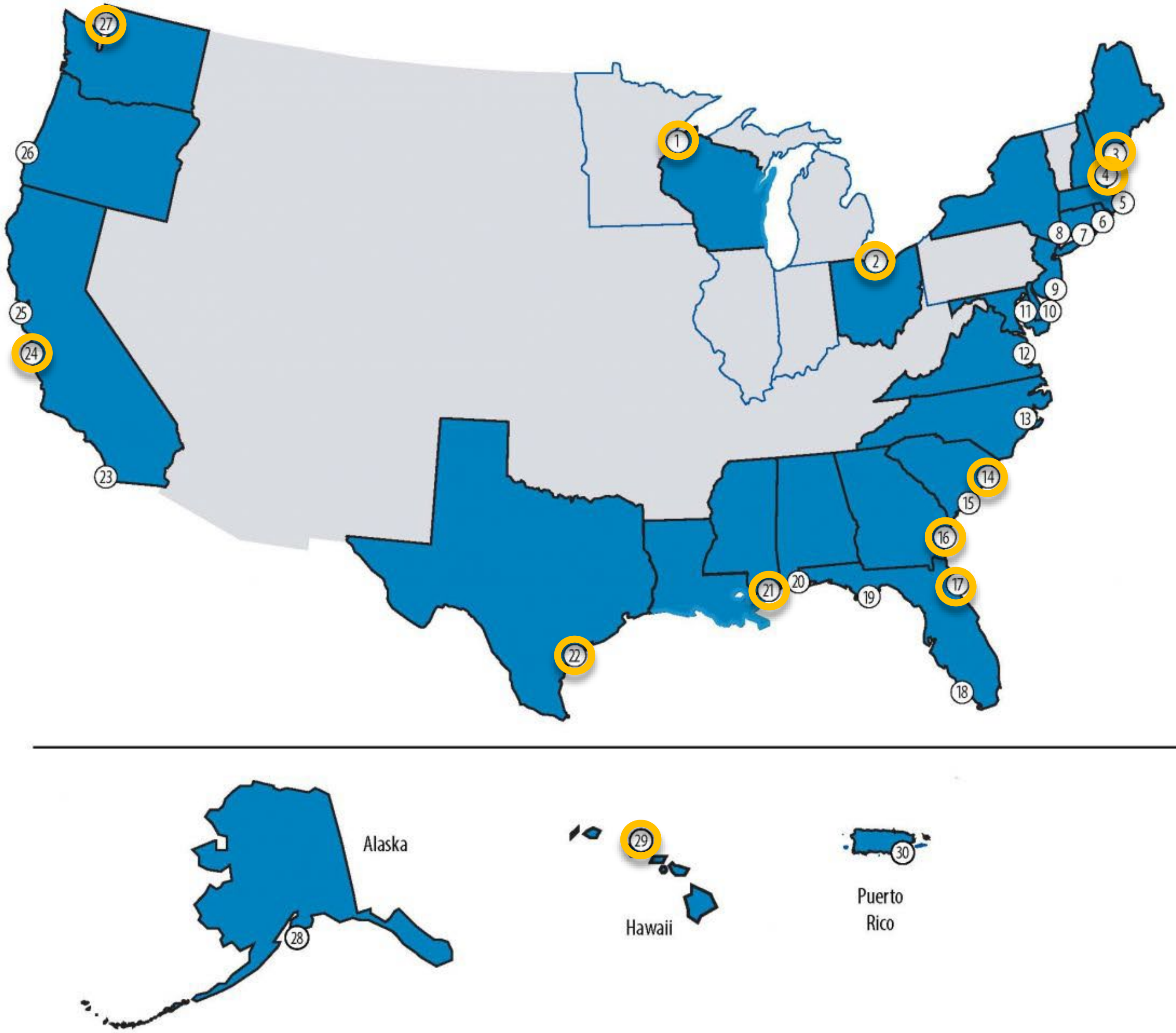
# Chlorophyll Catalyst Project


<u>Purpose</u>:
Assess the YSI EXO TAL sensor performance and make recommendations for the NERRS regarding inclusion of high-frequency, *in situ* chlorophyll *a* measurements in the SWMP

Dec 2020 – Feb 2022

National Estuarine Research Reserves
Science Collaborative

# NATIONAL ESTUARINE RESEARCH RESERVES

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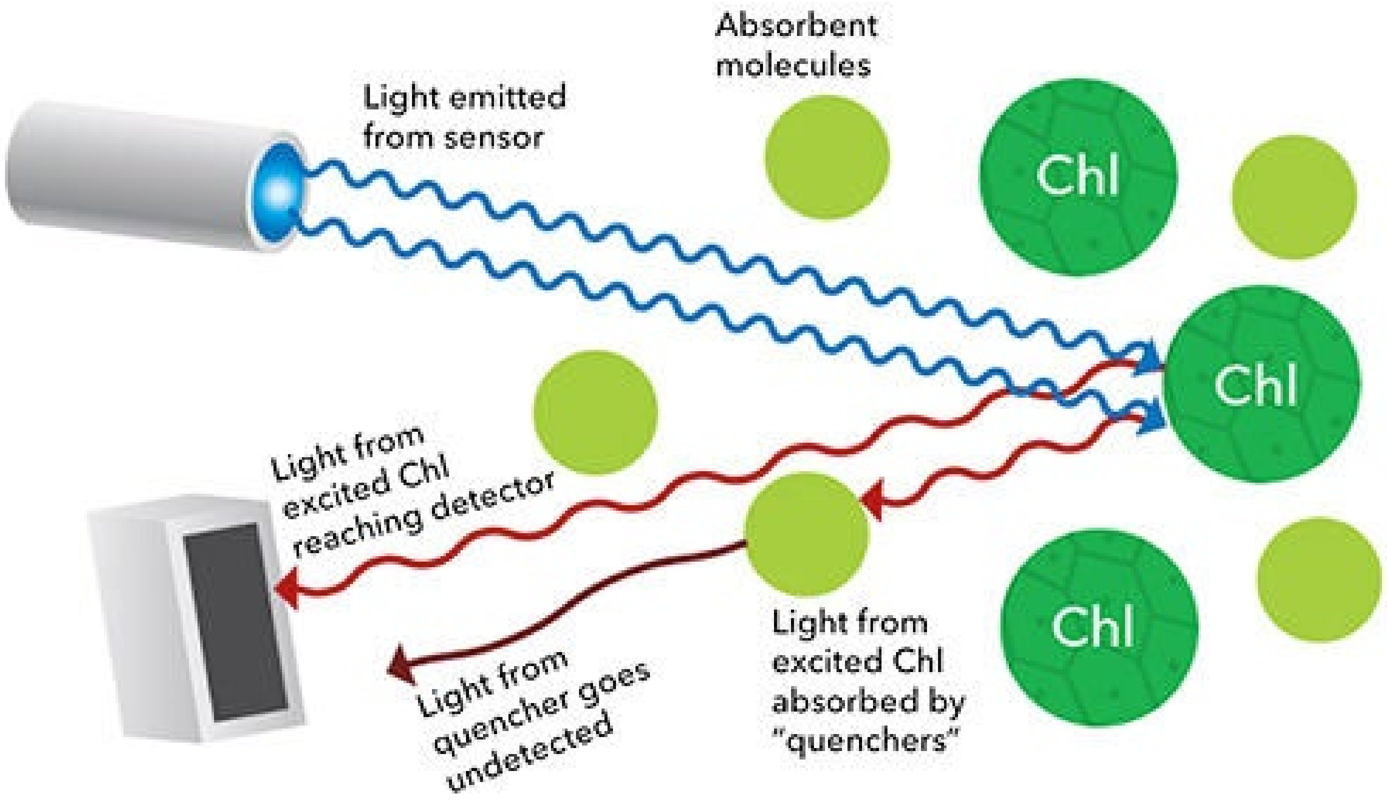
30. Jobos Bay, Puerto Rico

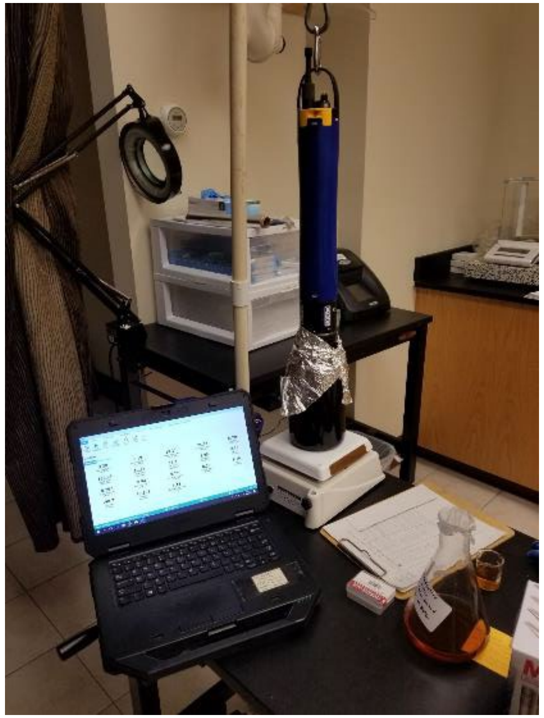
**PROPOSED**
Bay of Green Bay, Wisconsin
Louisiana

**Question 1**: How do temperature, turbidity, and FDOM influence CHL-A fluorescence (RFU) measured with the YSI EXO TAL sensor?

# Methods – Interference Experiments

Turbidity experiment at North Inlet

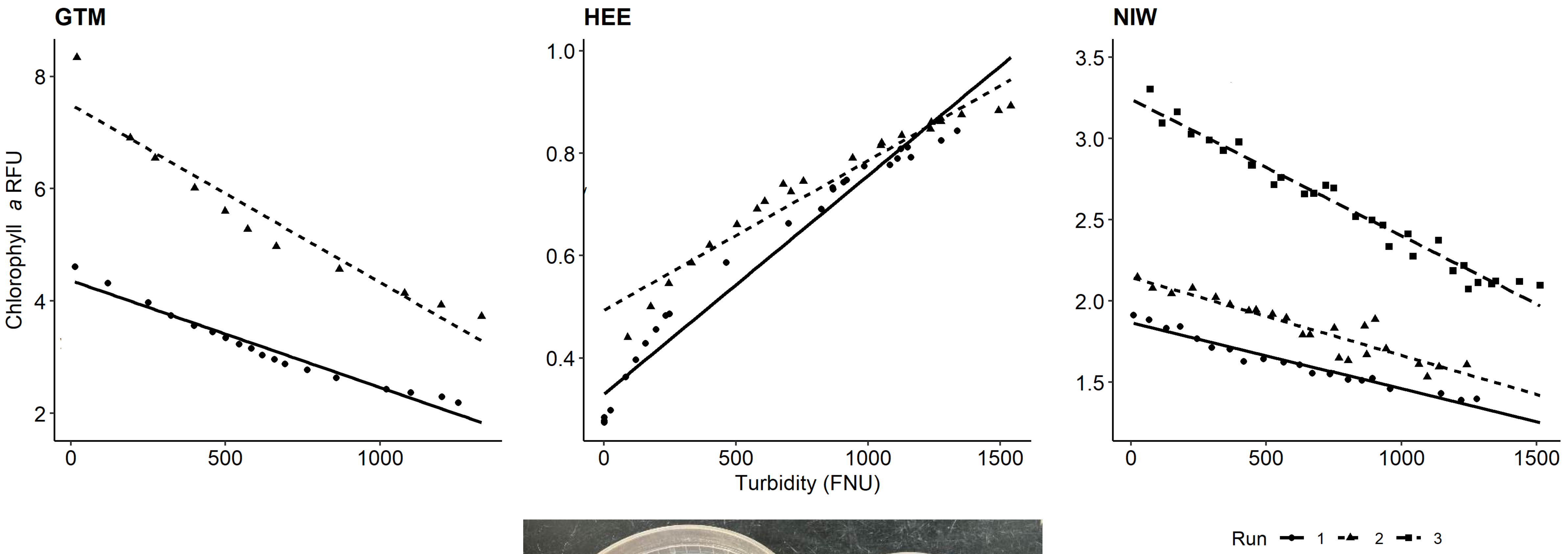


FDOM experiment at Lake Superior


Turbidity standard

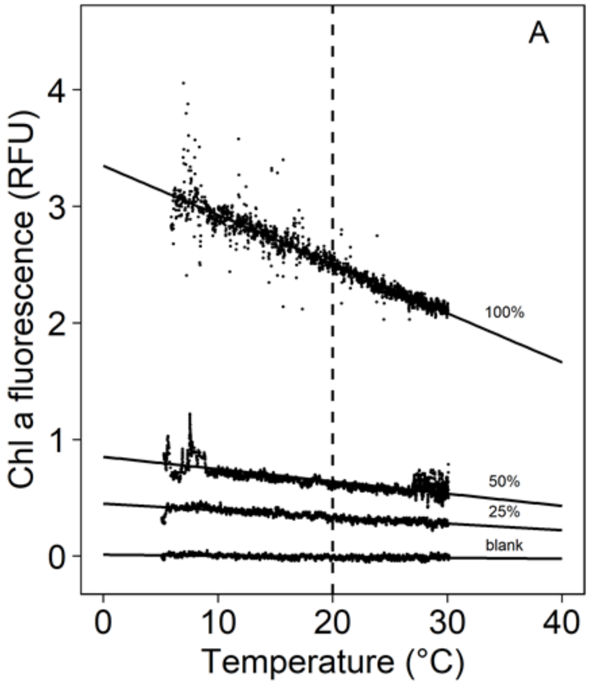

FDOM standards

# Results – Turbidity Effect

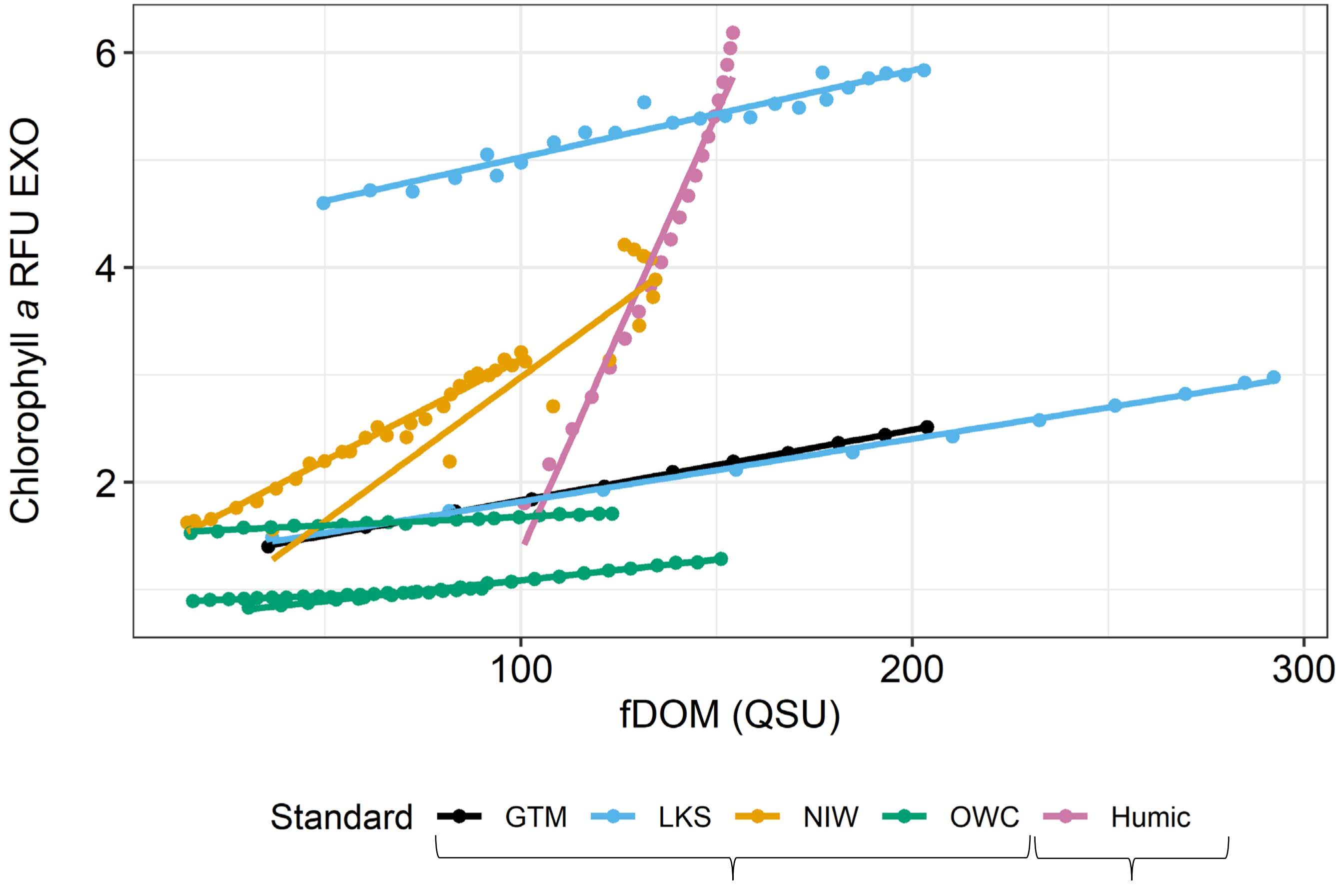


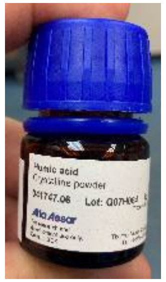

# Results – Temperature Effect

**NIW**



# Results – FDOM Effect



**Question 2**: How can we best predict extracted CHL-A (µg/L) from the suite of YSI EXO sensors?


# Methods – Field-Based Comparisons

GTM

He‘eia

Padilla Bay

Wells

# Methods – Lab-Based Comparisons

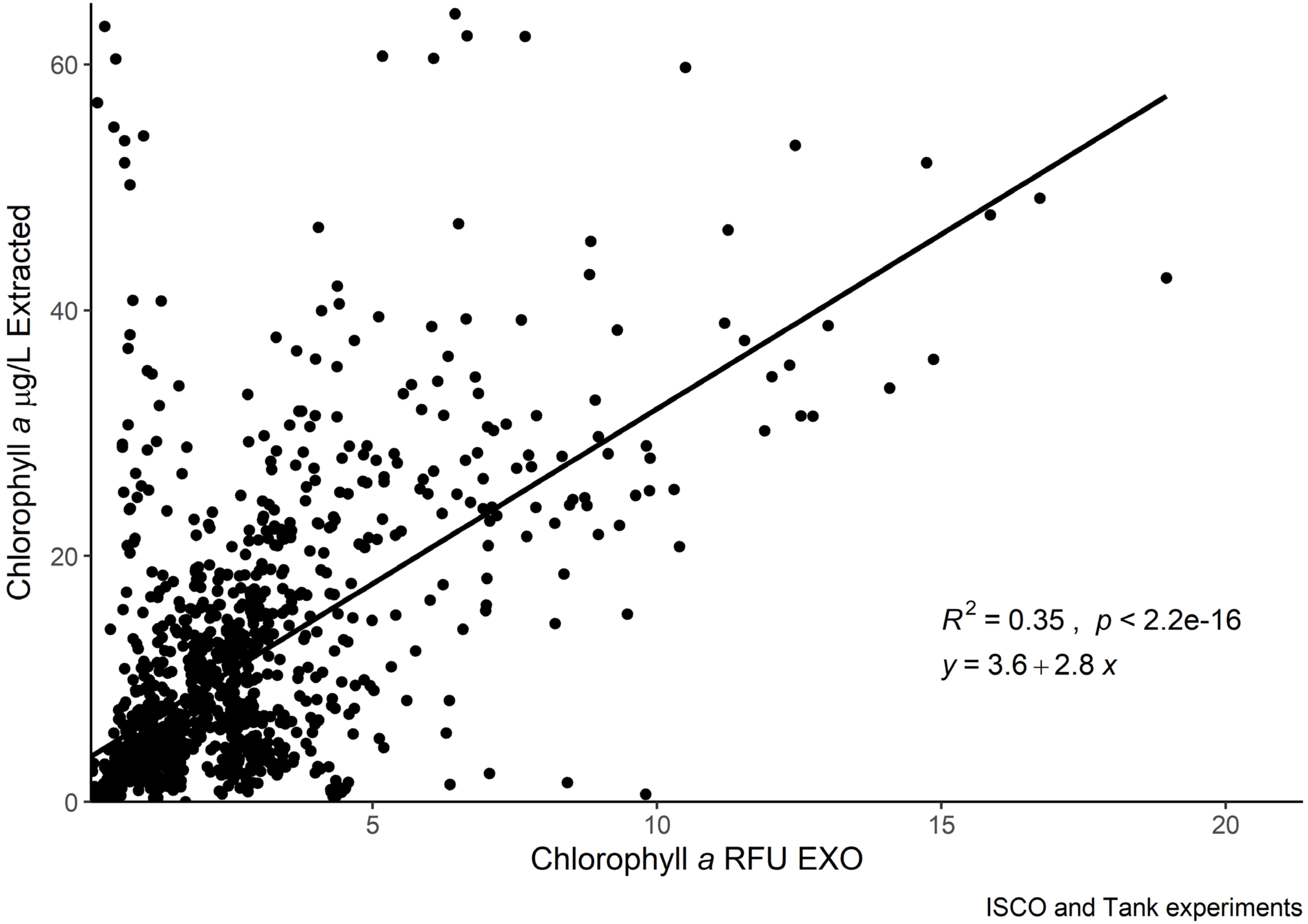
GTM

North Inlet-Winyah Bay

He‵eia


Mission Aransas

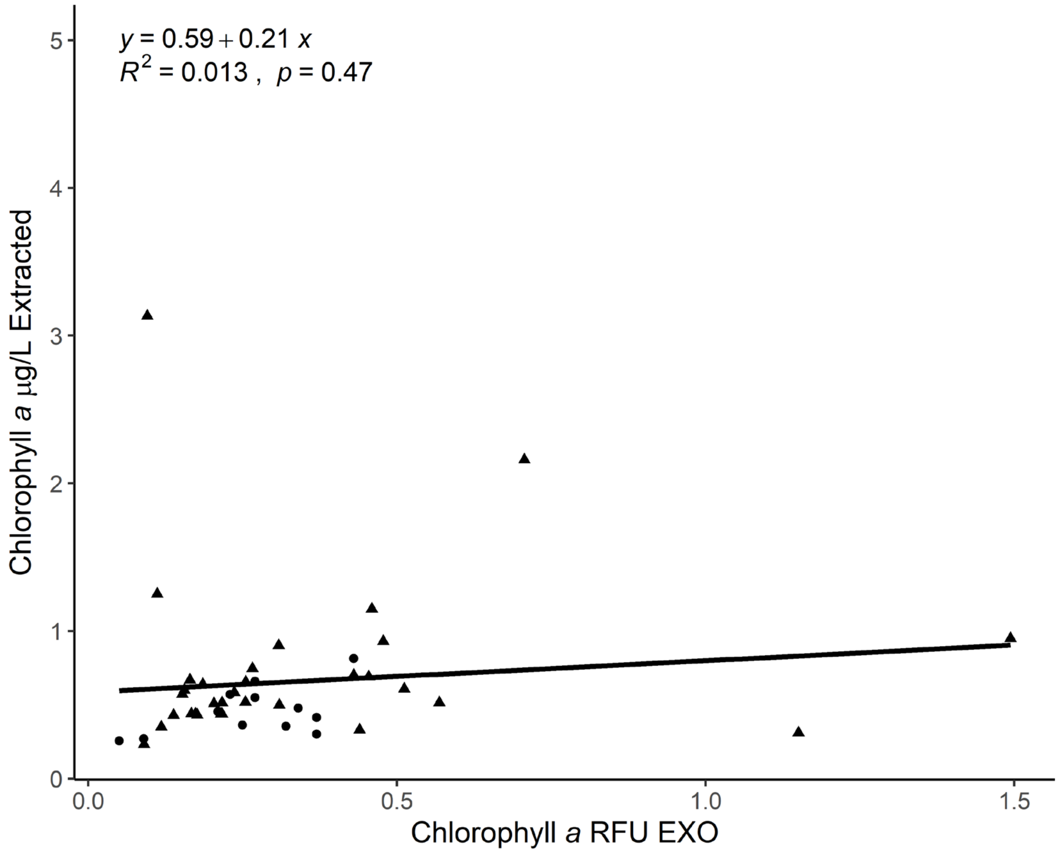
# Results - Comparisons



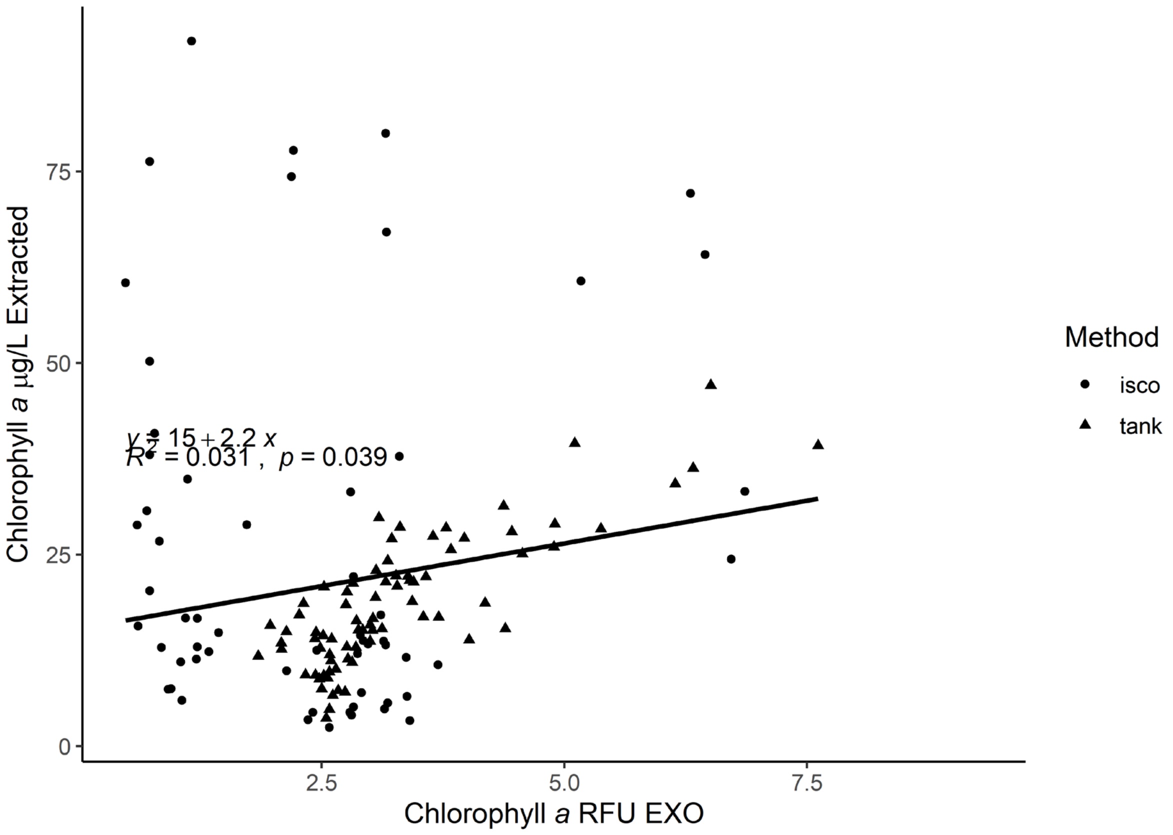

n = 1255

# Results - Comparisons

## Heʻeia, HI

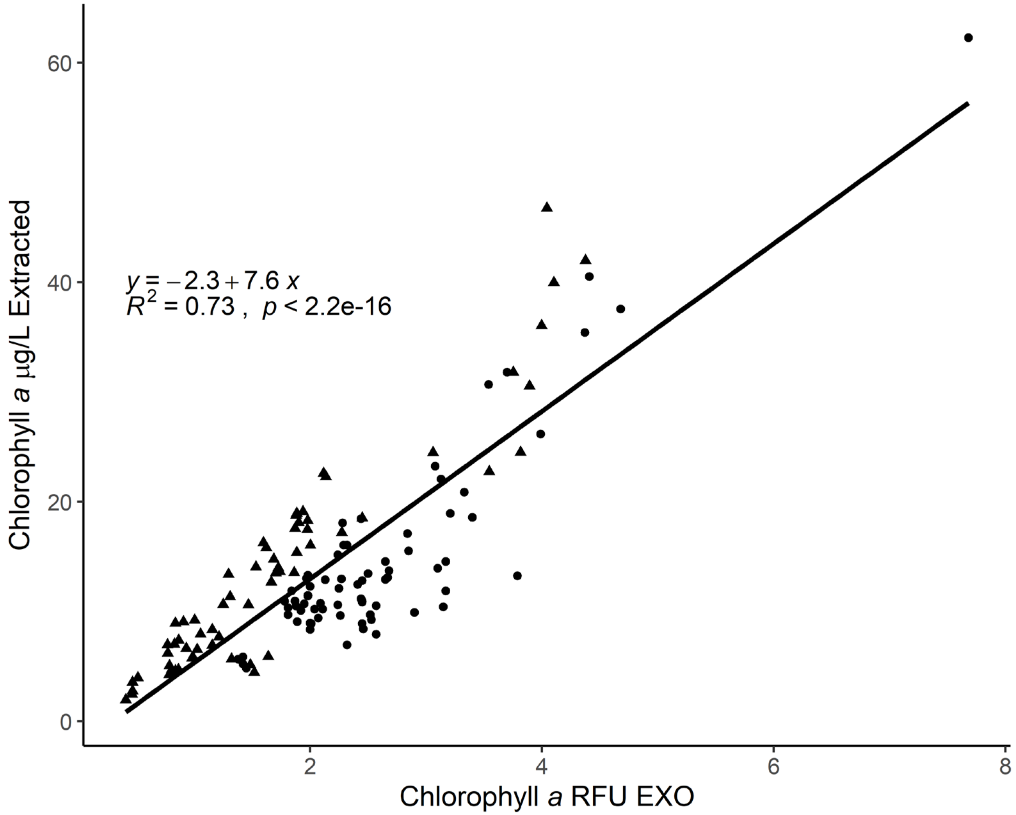



## Lake Superior, WI

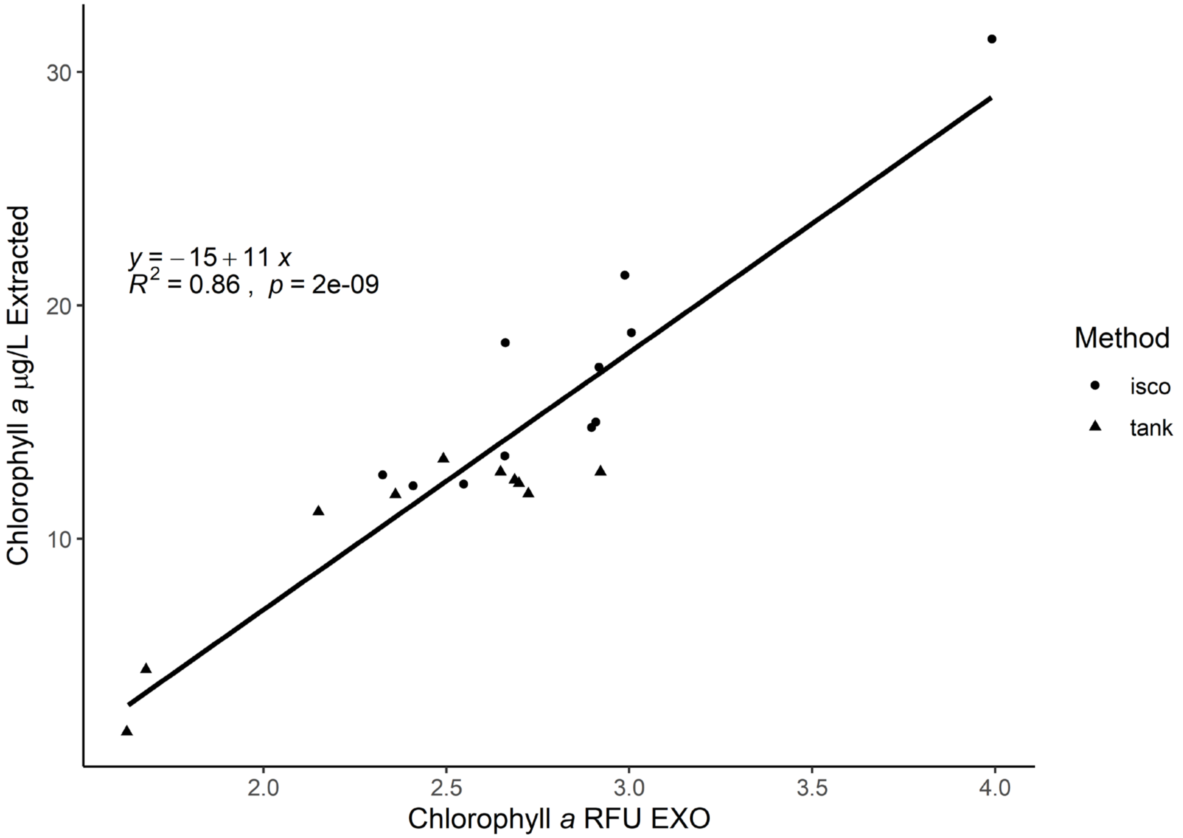


# Results - Comparisons

## North Inlet-Winyah Bay, SC




## Grand Bay, MS



# Methods – Data Analysis

<u>Main question</u>

How can we best predict extracted CHL-A (µg/L) from the suite of YSI EXO sensors?

<u>Models</u>

- both national and site-specific
- Ordinary Least Squares Linear Regression using data from comparisons

**Chl_extracted ~ chl_RFU + reserve + season + turb + FDOM + temp + interactions…**

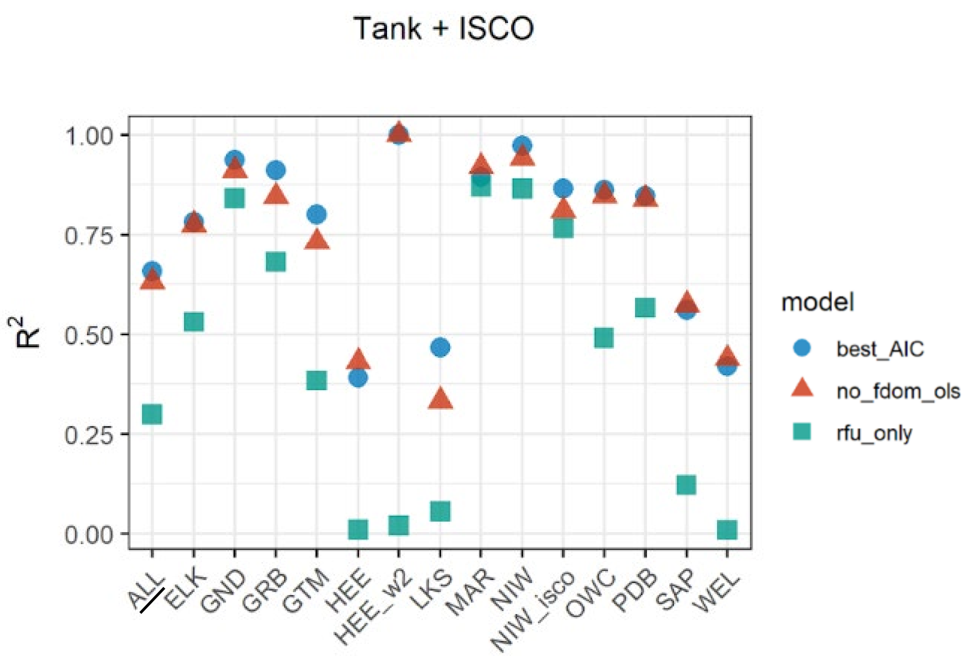
- Square root transformation
- AICc to pick "best" model

**Chl_extracted ~ chl_RFU + reserve + season + turb + temp + interactions…**

**Chl_extracted ~ chl_RFU**

- $R^2$ & prediction error to compare to "best" model

# Results – Data Analysis




Full model, best AICc

Full model without FDOM

RFU only

# Conclusions

- Temperature, turbidity, and FDOM influence CHL-A (RFU) readings from the YSI EXO TAL sensor.
- Correcting CHL-A (RFU) using data from the accessory sensors is not straightforward.
- Overall, when CHL-A (RFU) and extracted CHL-A were measured simultaneously, linear models of CHL-A RFU explained 35% of the variance in extracted CHL-A. Predictive capability increased when other sensor data and only lab-based comparison data were included ($R^2$ = 0.79).
- The amount of variance not explained by the model is likely a combination of species composition, chlorophyll degradation, light history, and interferences
- Site-specific factors are important in determining the strength and the drivers of the relationship between CHL-A (RFU) and extracted CHL-A.

# Recommendations

- We recommend NERRS begin implementing high-frequency chlorophyll monitoring system-wide, but this sensor is not a direct substitute for extractive CHL-A analysis.
- Recommendations for whether and how NERRs and others choose to implement the EXO TAL sensor depend on the chlorophyll monitoring goals for each individual station and resources available.

# Considerations

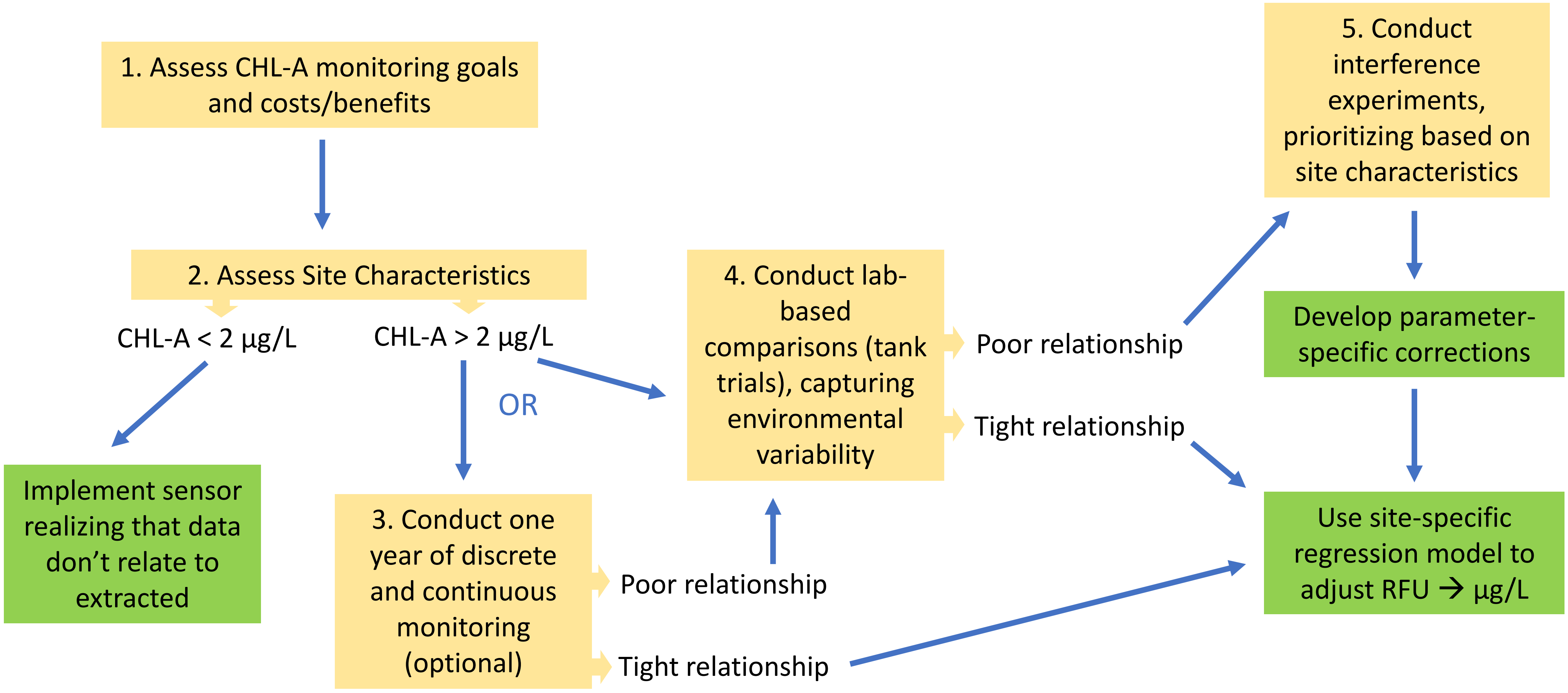
- All CHL-A methods have caveats when estimating phytoplankton biomass (e.g., photoacclimation, quenching).
- There is more potential for erroneous readings with *in-situ* CHL-A because of interferences.
- Monthly CHL-A measurements are not frequent enough to capture short-term plankton dynamics.
- Potential applications for real-time *in-situ* CHL-A data
  - More research (ecosystem metabolism, HAB prevention, etc.)
  - HAB early detection, rapid response (if telemetered)
- Costs
  - TAL sensor $3,150
  - FDOM sensor $2,394
  - Calibration time
  - Waste

## Project Page

https://nerrssciencecollaborative.org/project/Dix20

National Estuarine
Research Reserves
Science Collaborative

# Recommendations



# Q&A

**Q: Did you consider using other manufacturer's sensors, especially those that account for LED degradation?**

- **A**: No, our project was specifically interested in testing the YSI sensors at multiple reserve sites, but that would be a good next step for future work.

**Q: Have you needed to develop site-specific relationships between grabs and sondes?**

- **Erik** - Yes, we showed there was a site interaction in the overall model, and so the relationship varied across site including the degree to which interfering substances impacted the model.
- **Nikki** - each of us only looked at individual sites, each of us will now need to go to our other sites and do the same thing.

**Q: Based on your experience, could we establish a list of lakes/reservoirs that are suitable (i.e., lower TSS, CDOM) for such monitoring with in situ chlorophyll-a sensors?**

- **A**: We talked about that a little bit. We did end up recommending a threshold of about 2 micrograms per liter. If you have really low chlorophyll, we think there’s probably too much noise-to-signal ratio to predict extracted chlorophyll.

**Q: How does the cost of adding a fluorescence sensor package compare to increased grab sampling, say going from 1/month to 4/month?**

- **A**: It depends on whether you do your chlorophyll analysis in-house or pay a lab to do it. Ultimately, there’s no way you’re going to get anywhere close to the frequency you get with these sensors if you’re collecting by hand; not to mention having access blocked by storms or other events.

**Q: Can you explain more about what "light history" is and why it might be an interference in this study?**

- **A**: Phytoplankton cells can reduce chlorophyll if there is a lot of light, and vice versa, to adapt to their conditions. We don’t think it was a significant source of interference in our project as we had everything acclimated to dark tanks when we did our lab based comparisons.

**Q: For the consideration of measurements, was consideration of the turbidity categorized (i.e. differentiating between soil particles, algae, microbes, etc.)?**

- **A**: That digs a bit deeper than we could do in this first cross-system assessment. Our goal is really to use a standard, albeit natural, source of turbidity to get a first cut and see how it varied across systems.

# Q&A

**Q: Is the strength of the relationship between extracted and in situ chlorophyll-a also impacted by the signal to noise ratio?  For example, North Inlet-Winyah Bay NERR has a strong relationship with more instances of elevated chlorophyll a, whereas He'eia NERR has a poor relationship but also low chlorophyll.**

- **A**: We didn't actually test for a statistical relationship, but we think probably yes based on the general pattern we observed, with some deviations (e.g., Old Woman Creek, OH had one of the highest values of chlorophyll but one of the lowest correlations). We'd have to test it – there were other variables such as FDOM and turbidity that act as compounding interferences.

**Q: Was any measurement performed after a celestial event (such as a solar flare) or atmospheric event (i.e. a big downpour or snow day)?**

- **A**: Not that I know of. We all tried to sample across a full range of natural variability in the season, but unfortunately, no solar flares.

**Q: Can you say a bit more about the calibration process?**

- **A**: The calibration was based on what YSI recommends as a two-point calibration using a rhodamine fluorescent dye, and then kind of a mixture of our SWMP protocols as far as rinsing and cleaning. In the YSI manual they also have instructions on how you can perform a one-point calibration with zero, so pure water. Consistent with SWMP protocols, we generally follow the manufacturer's recommendations.

**Q: Even if there is not always a strong relationship between extracted and in situ chlorophyll, do you still think it is a good proxy for something ecologically relevant?  We have found that in situ chlorophyll-a changes in meaningful ways to other environmental factors.**

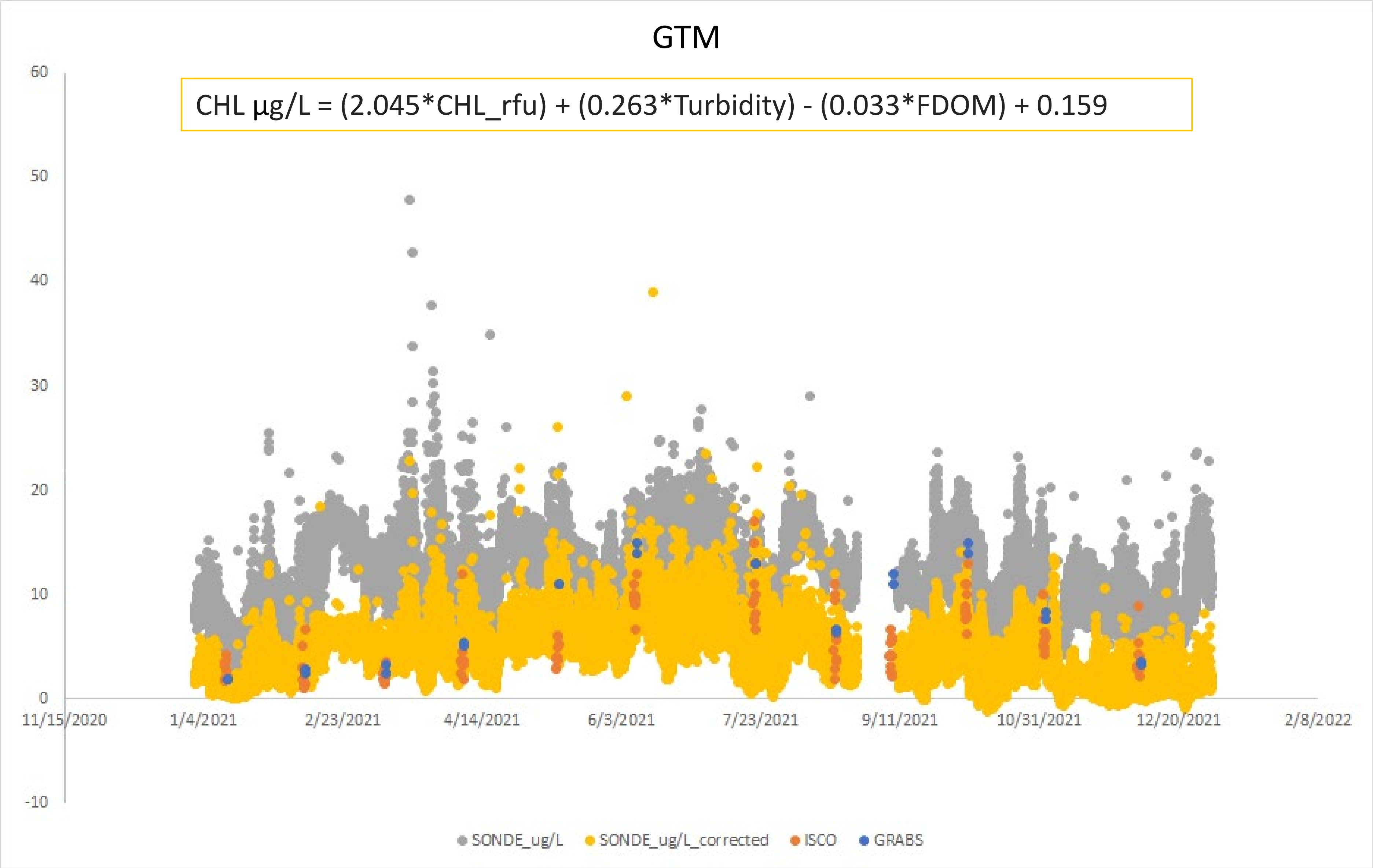
- **A**: We think so. It's especially valuable being able to get measurements on the hourly to daily time scale. The question is: when you get spikes or really elevated values, you don't know for sure if that's turbidity or an FDOM spike that's inflating those values. So it's more like an early warning system for letting you know there could be something there.

# Comments

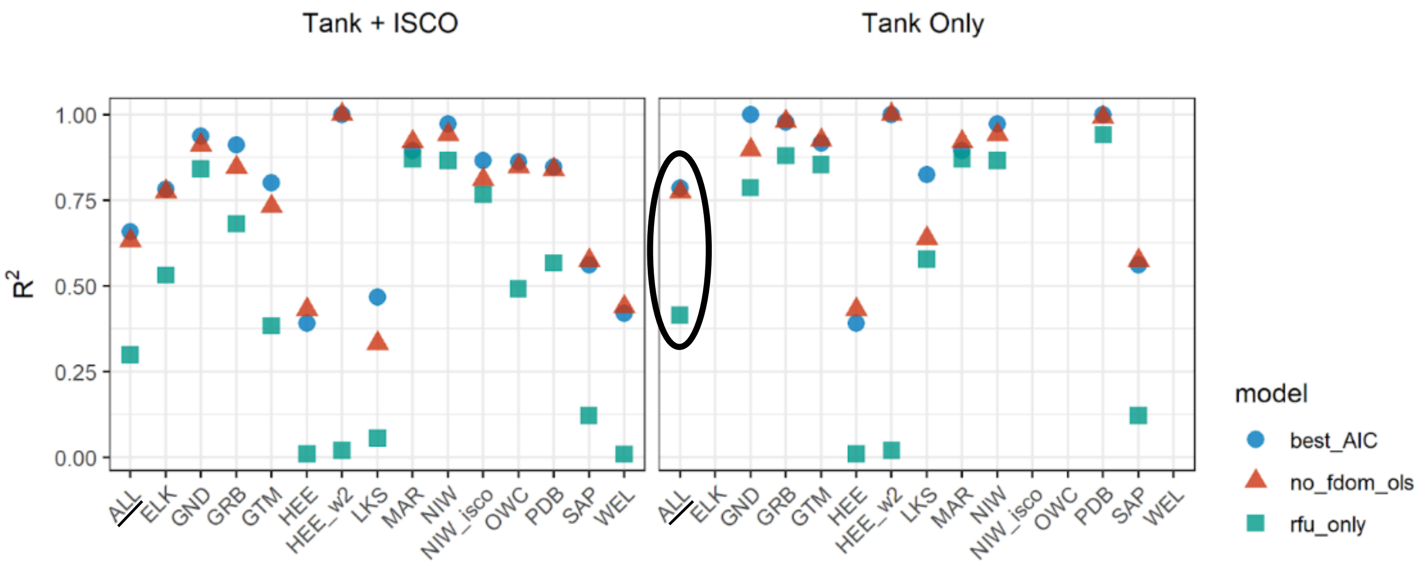
*This was really great, folks.  I'm impressed with your work and the site-specific relationships were very encouraging; I'd even say surprising.  I look forward to seeing more!*

*Great presentation and project! will be super helpful, I think, for us in Great Bay Estuary, since we had a particular high r-square. Thank you very much!*

# Adjustment Example

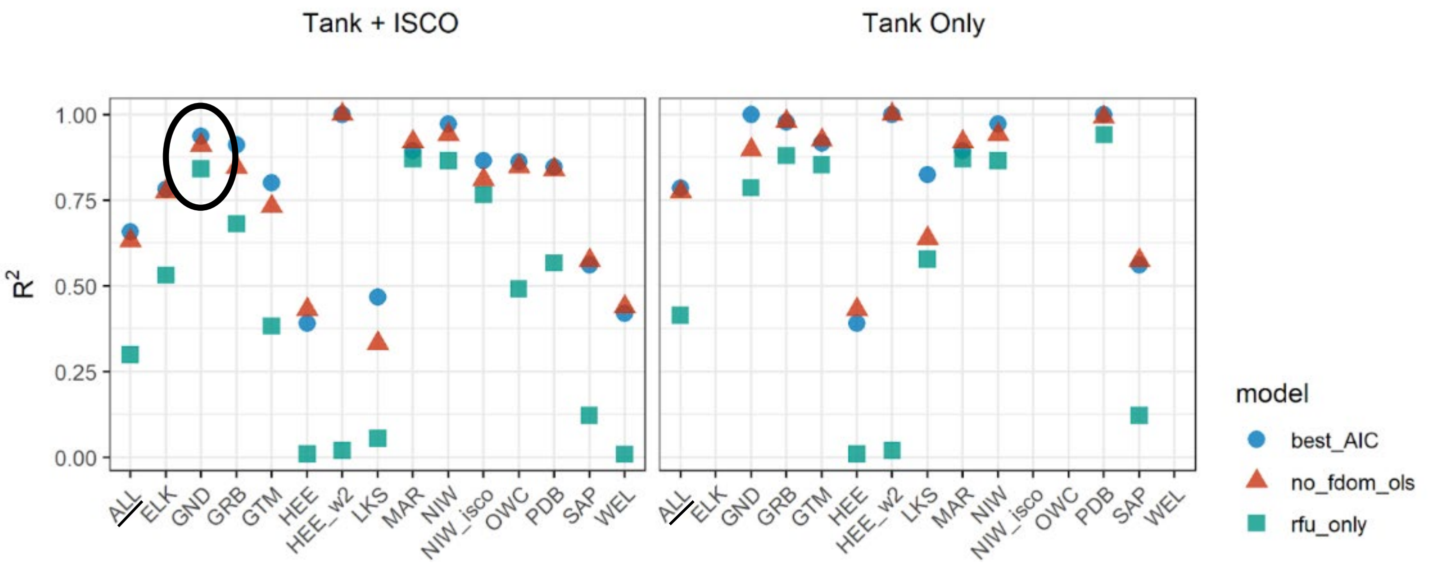


# Results – Data Analysis




| model | R2 | prediction _error | sensor_rfu | fdom_qsu | turb | season | reserve | temp | X.Intercept . | fdom_qsu. sensor_rfu | fdom_qsu. temp | fdom_qsu. turb | sensor_rfu .temp | sensor_rfu .turb | fdom_qsu. sensor_rfu .turb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| best_AIC | 0.79 | 25.7 | 0.231 | 0.0032 | 0.1254 | NA | + | 0.0266 | 1.15 | 0.0013 | -6e-04 | NA | 0.0172 | -0.0265 | NA |
| no_fdom_ols | 0.77 | 26.7 | 0.414 | NA | 0.1085 | + | + | -0.0214 | 1.33 | NA | NA | NA | 0.0102 | -0.0238 | NA |
| rfu_only | 0.41 | 49.1 | 0.388 | NA | NA | NA | NA | NA | 2.18 | NA | NA | NA | NA | NA | NA |

# Results – Data Analysis




| Reserve | model | R.2 | prediction_ error | sensor_rfu | fdom_qsu | turb | season | temp | X.Intercept . | fdom_qsu. sensor_rfu | fdom_qsu.t emp | fdom_qsu.t urb | sensor_rfu. temp | sensor_rfu. turb | fdom_qsu. sensor_rfu. turb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ELK | best_AIC | 0.782 | 29.3 | 0.365 | 0.0242 | -0.0201 | + | 0.2324 | -1.216 | -0.012 | NA | NA | NA | NA | NA |
| ELK | no_fdom_ols | 0.775 | 29.9 | 0.497 | NA | 0.0247 | + | 0.2605 | -1.448 | NA | NA | NA | -0.0105 | -0.0166 | NA |
| ELK | rfu_only | 0.531 | 39.2 | 0.41 | NA | NA | NA | NA | 2.161 | NA | NA | NA | NA | NA | NA |