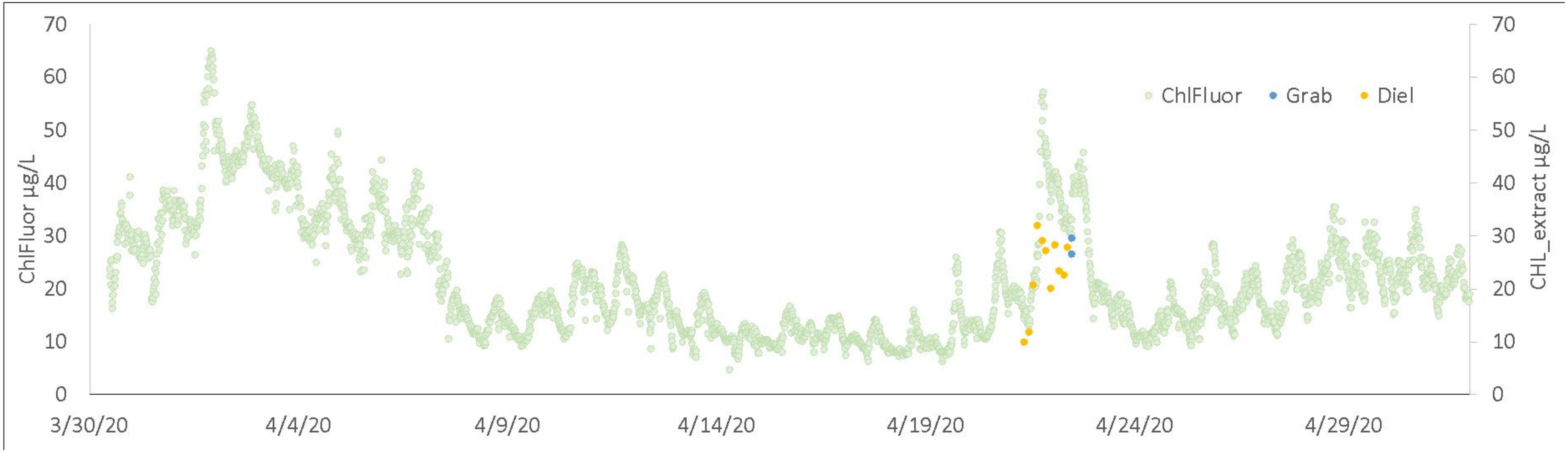
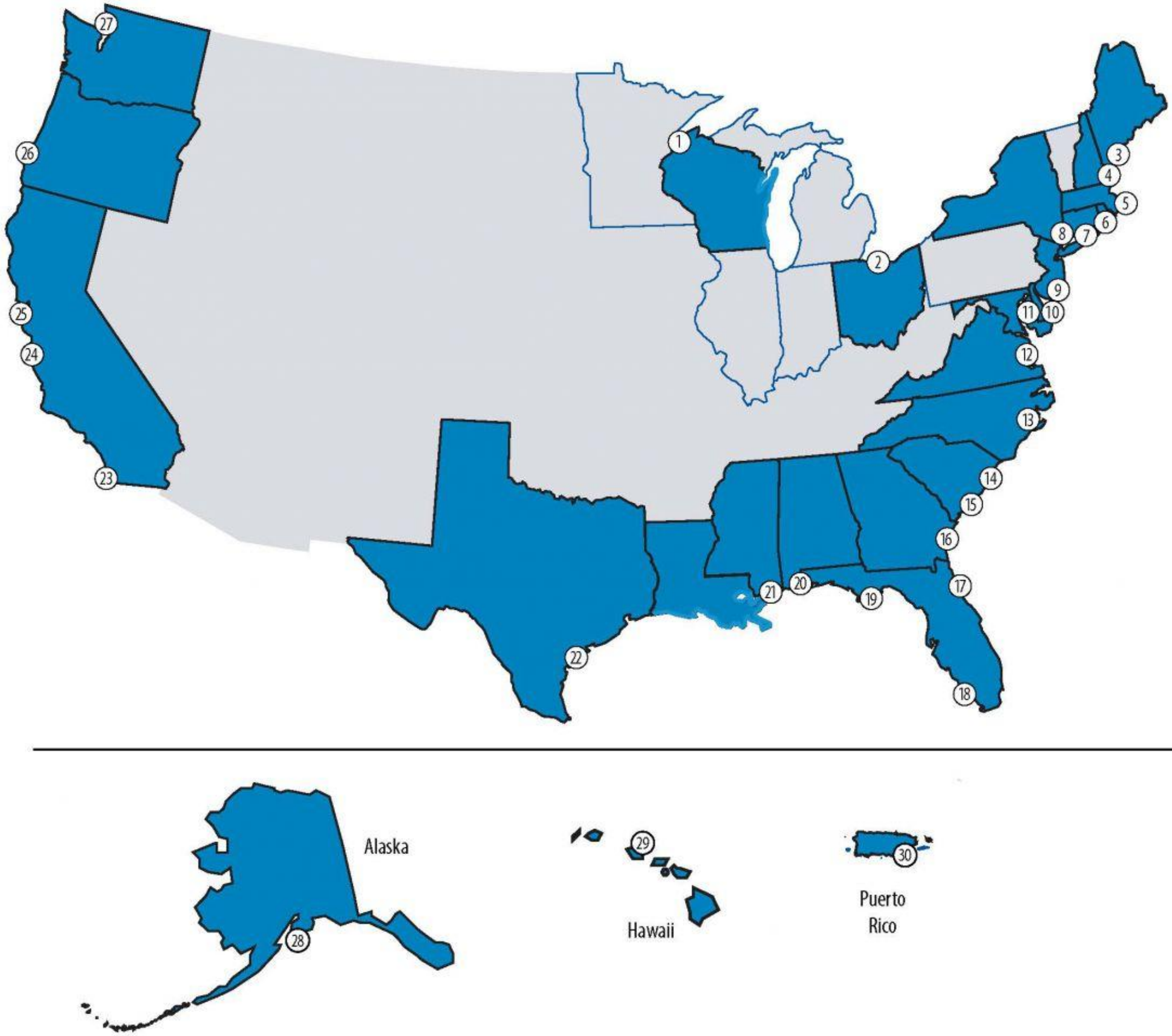
Refining techniques for high-frequency monitoring of chlorophyll *a* in the National Estuarine Research Reserve System

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

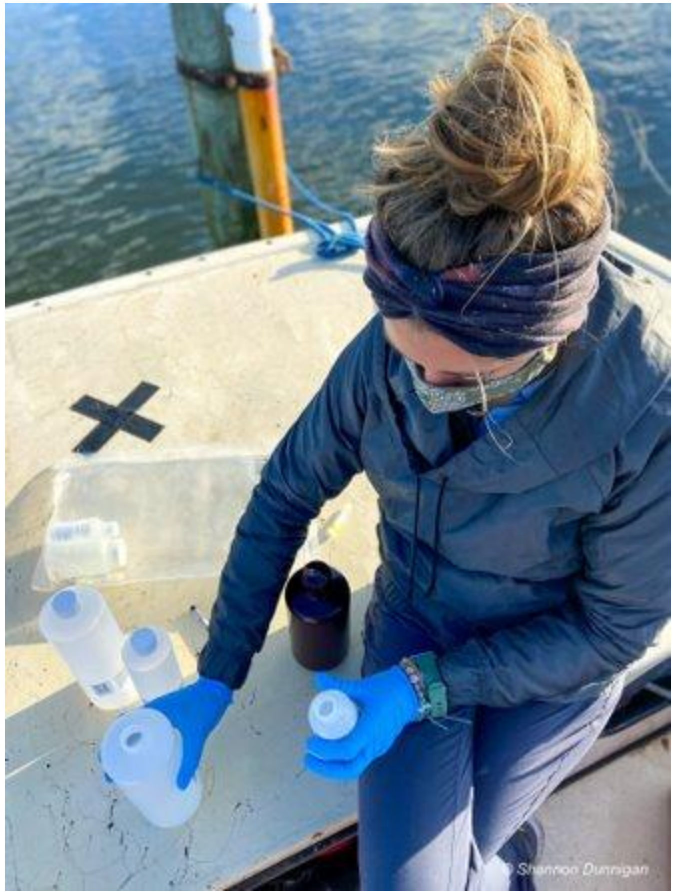
Pacific
29. He'eia, Hawai'i

Caribbean
30. Jobos Bay, Puerto Rico

PROPOSED

Bay of Green Bay, Wisconsin
Louisiana

System-Wide Monitoring Program



Chlorophyll *a*

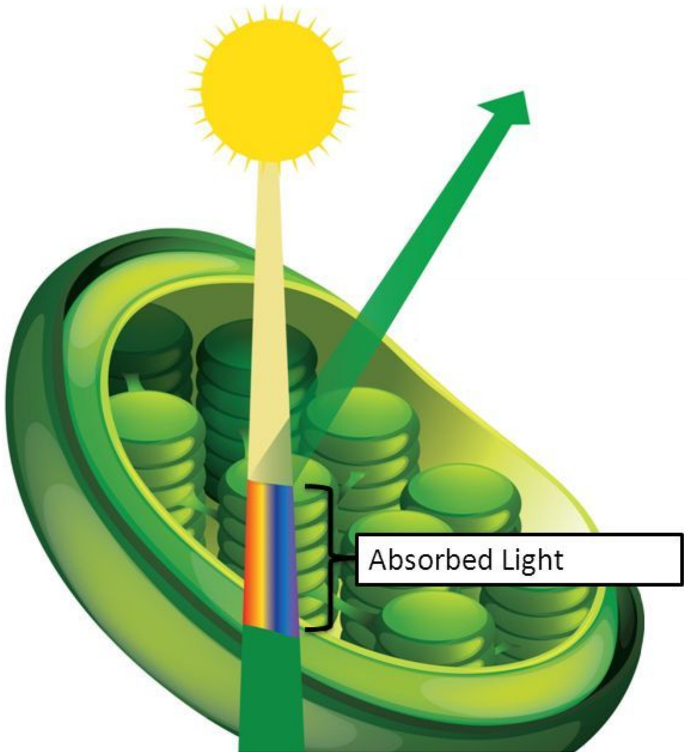
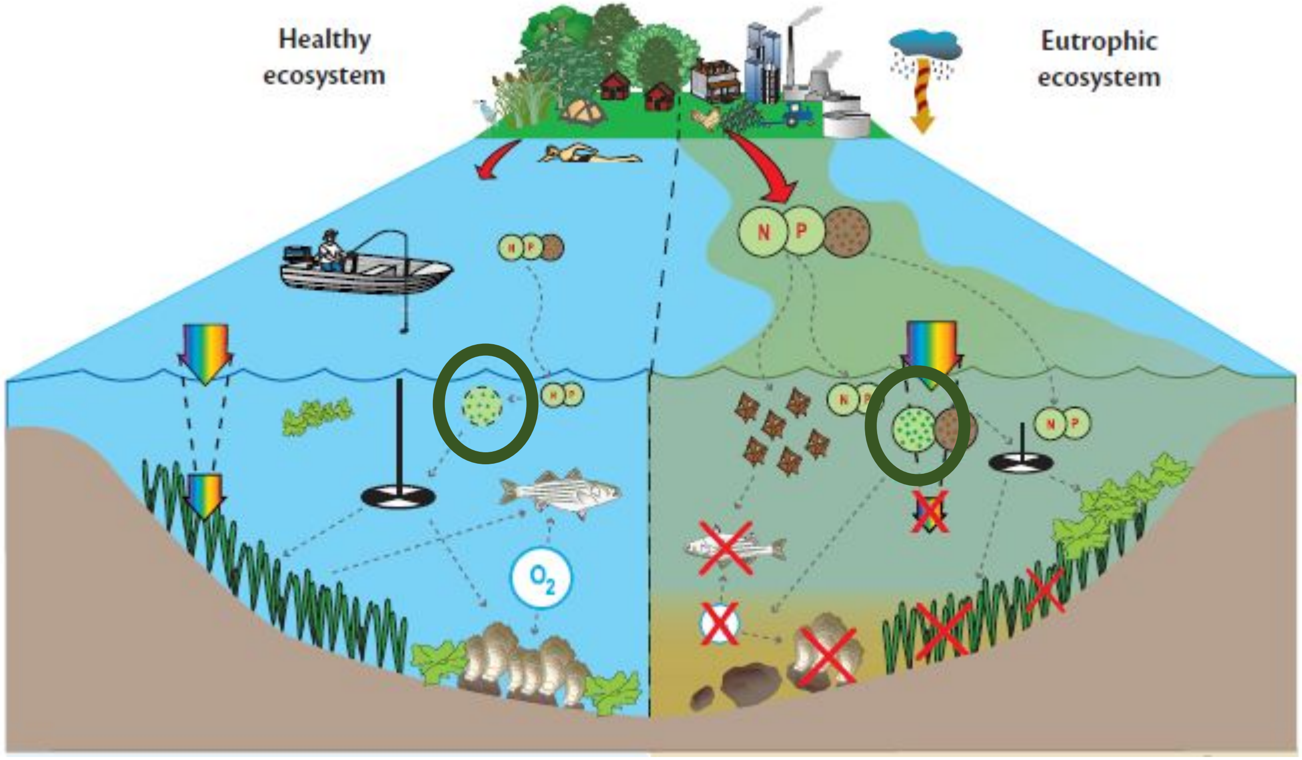


Image credit: https://slideplayer.com/slide/3922722/

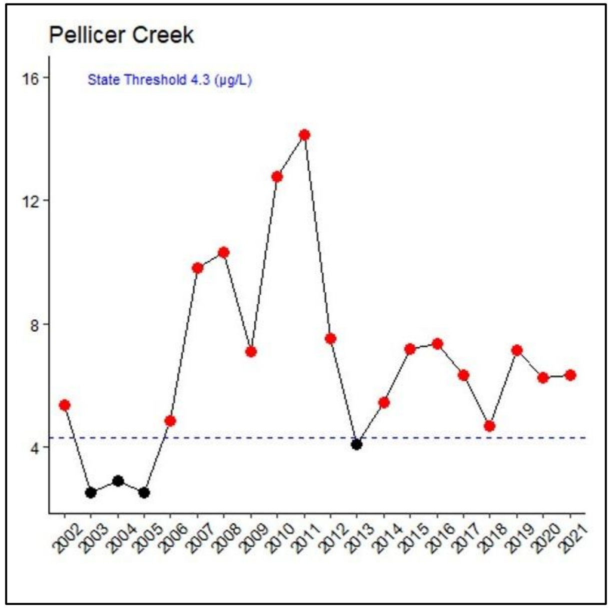


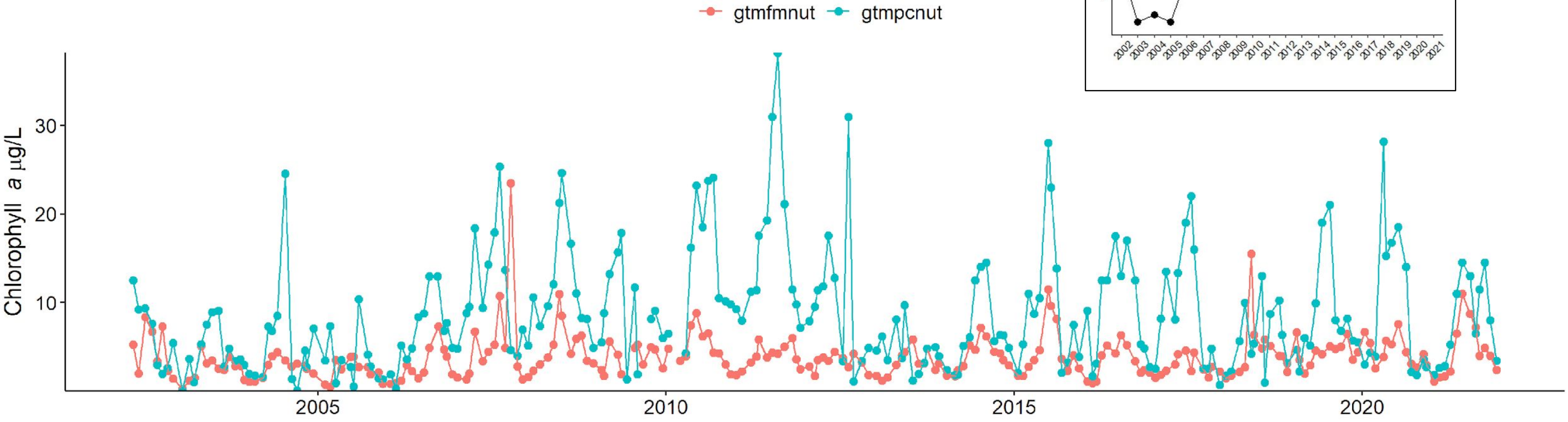
Bricker et al. 2007. Effects of Nutrient Enrichment In the Nation's Estuaries: A Decade of Change. NOAA Coastal Ocean Program Decision Analysis Series No. 26. National Centers for Coastal Ocean Science, Silver Spring, MD. 328 pp.

Monthly Discrete Monitoring

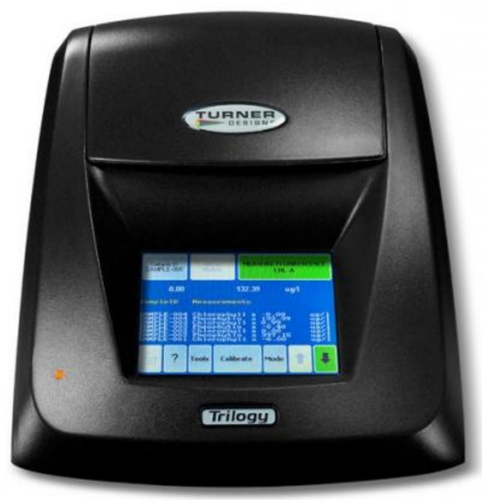
Valuable for

- Long-term trends
- Seasonality
- Trophic status





Extracted Chlorophyll *a*



In situ chlorophyll *a*

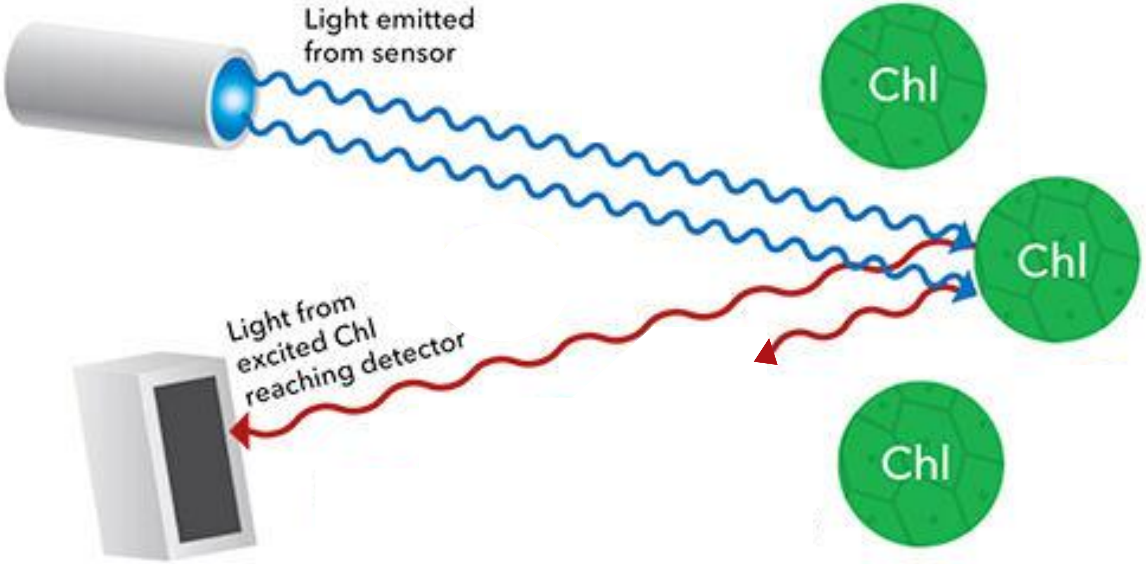
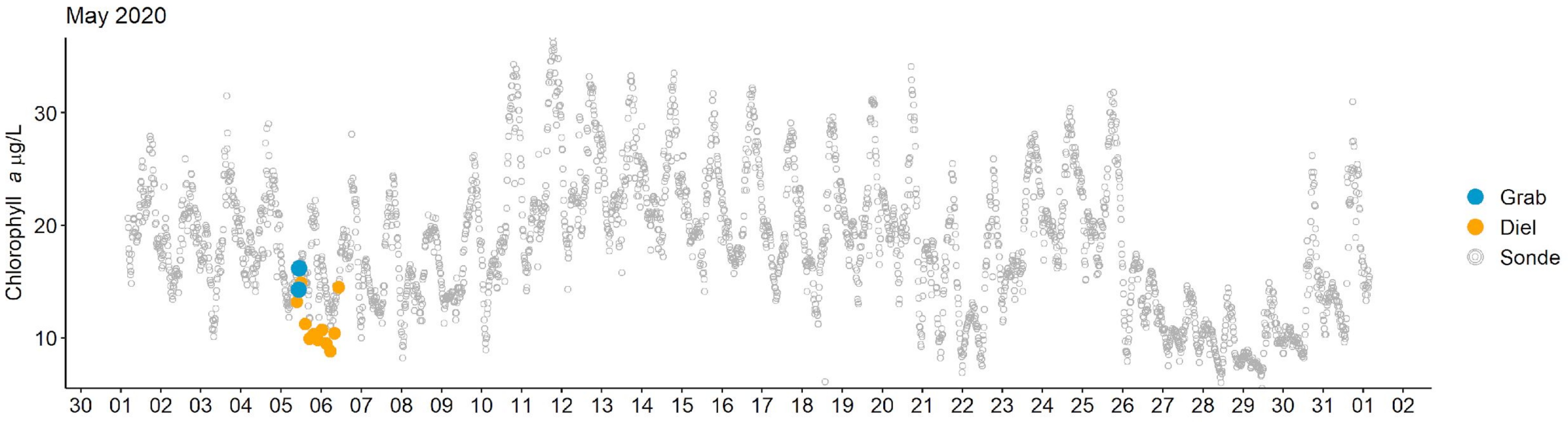


Image credit: www.ysi.com

In situ chlorophyll *a*

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



In situ chlorophyll *a*

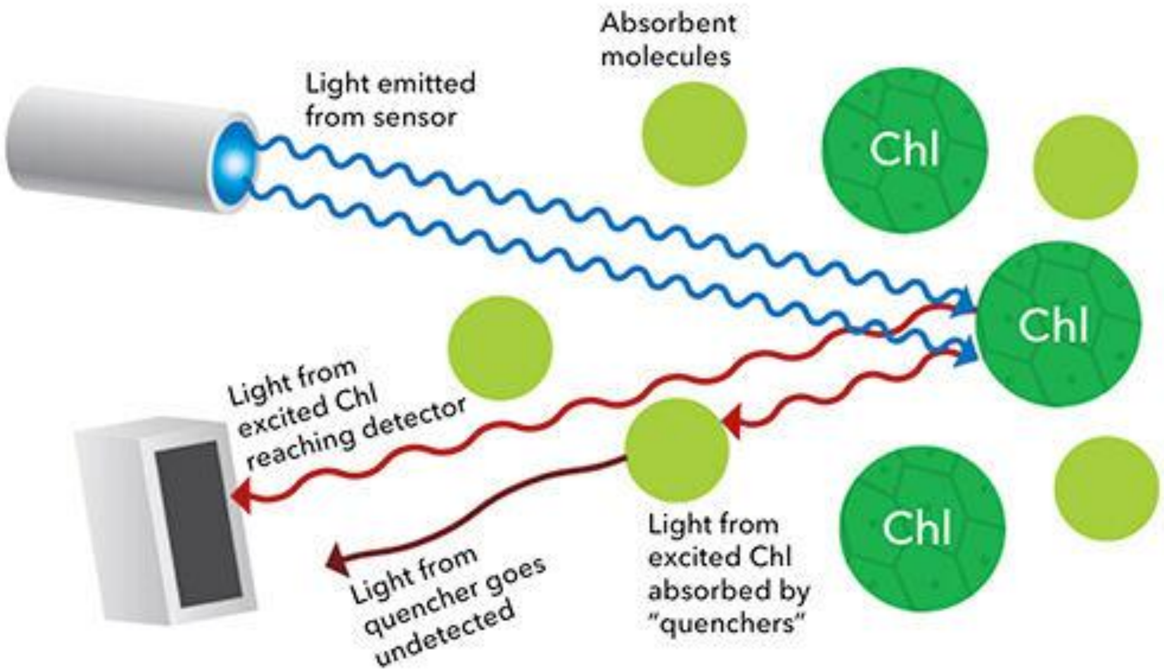


Image credit: www.ysi.com

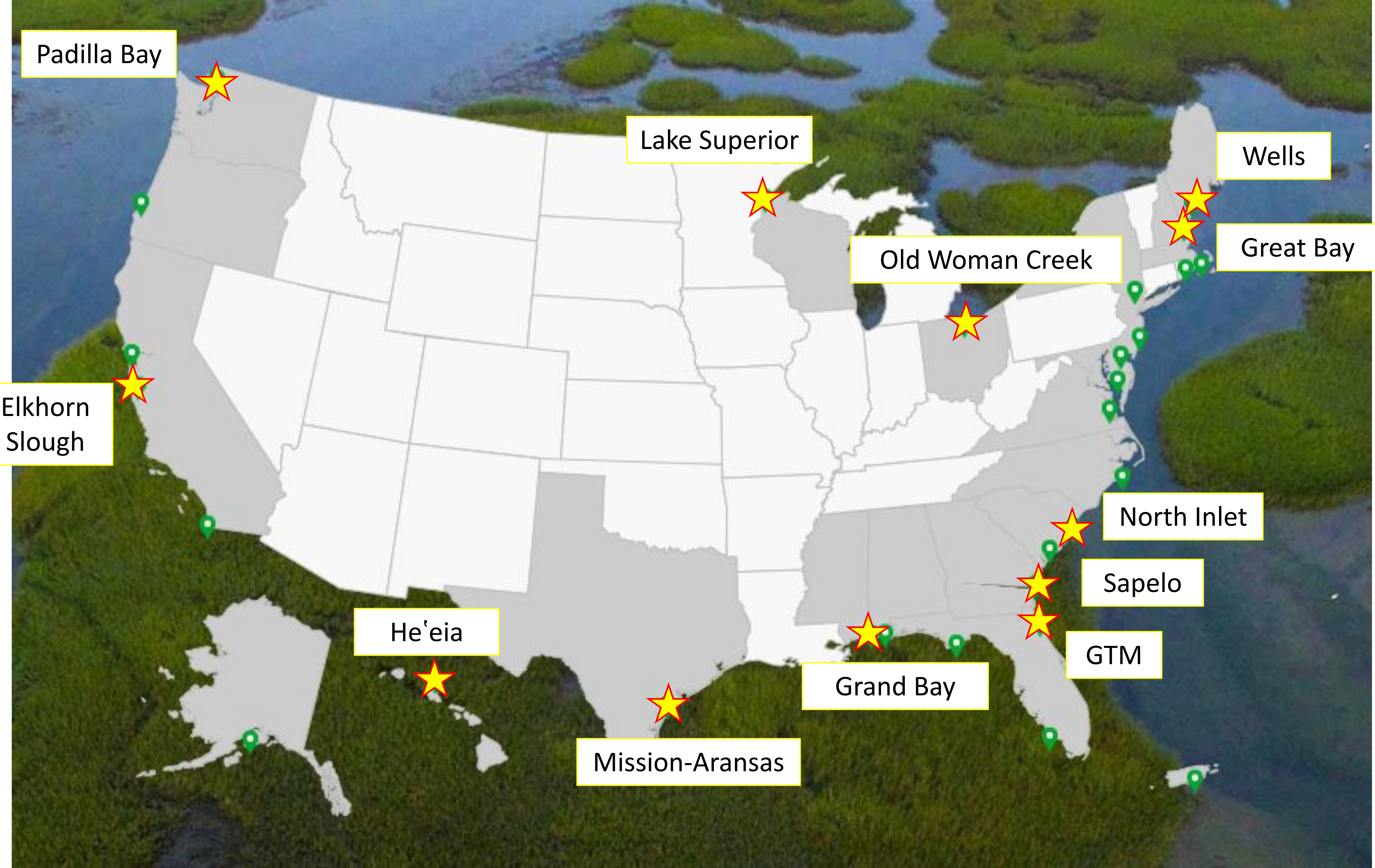
Chlorophyll Catalyst Project

<u>Purpose</u>:

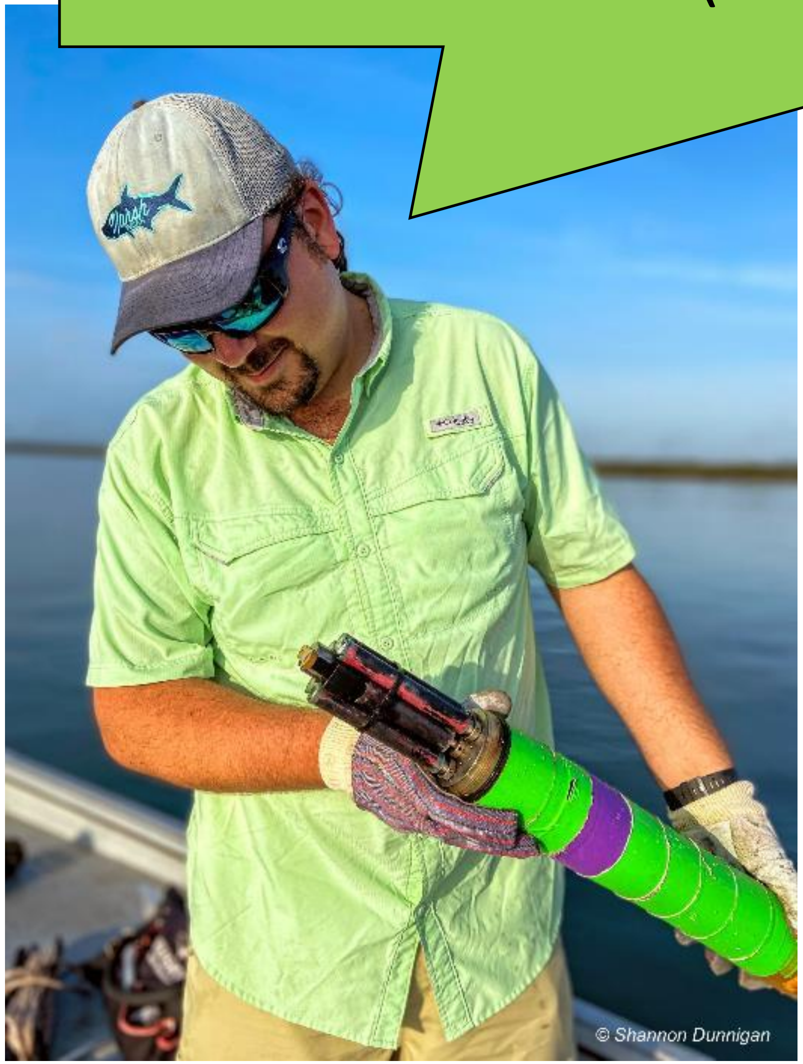
Assess the YSI EXO TAL sensor performance and make recommendations for the NERRS regarding inclusion of high-frequency, *in situ* chlorophyll *a* measurements in the SWMP

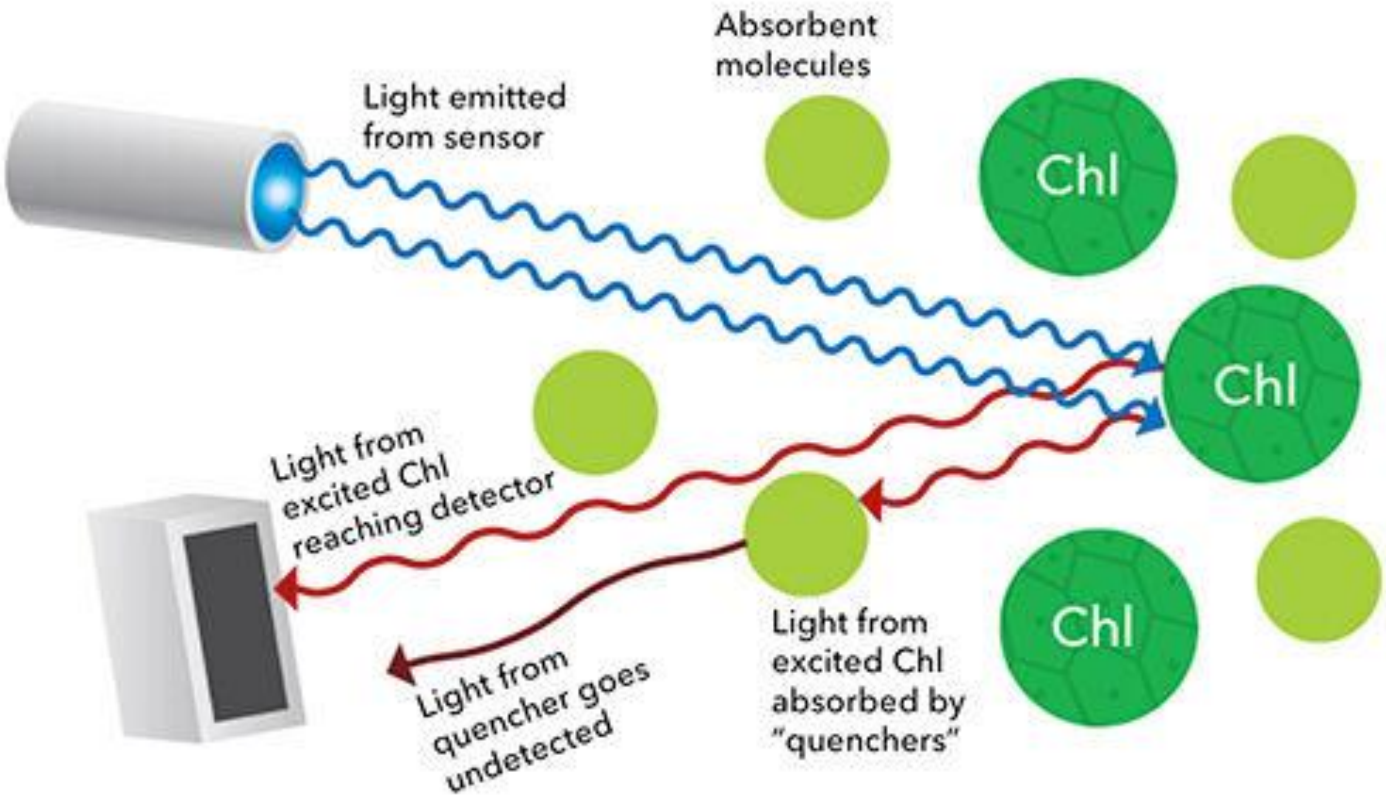
Dec 2020 – Feb 2022

National Estuarine Research Reserves
Science Collaborative


Padilla Bay
Lake Superior
Wells
Great Bay
Old Woman Creek
Elkhorn Slough
North Inlet
Sapelo
He'eia
GTM
Grand Bay
Mission-Aransas

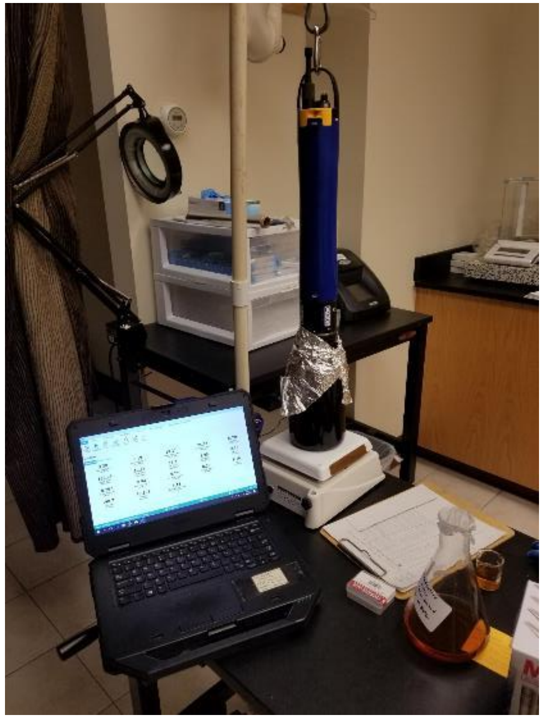
Question 1: How do temperature, turbidity, and FDOM influence CHL-A fluorescence (RFU) measured with the YSI EXO TAL sensor?





Methods – Interference Experiments

Turbidity experiment at North Inlet

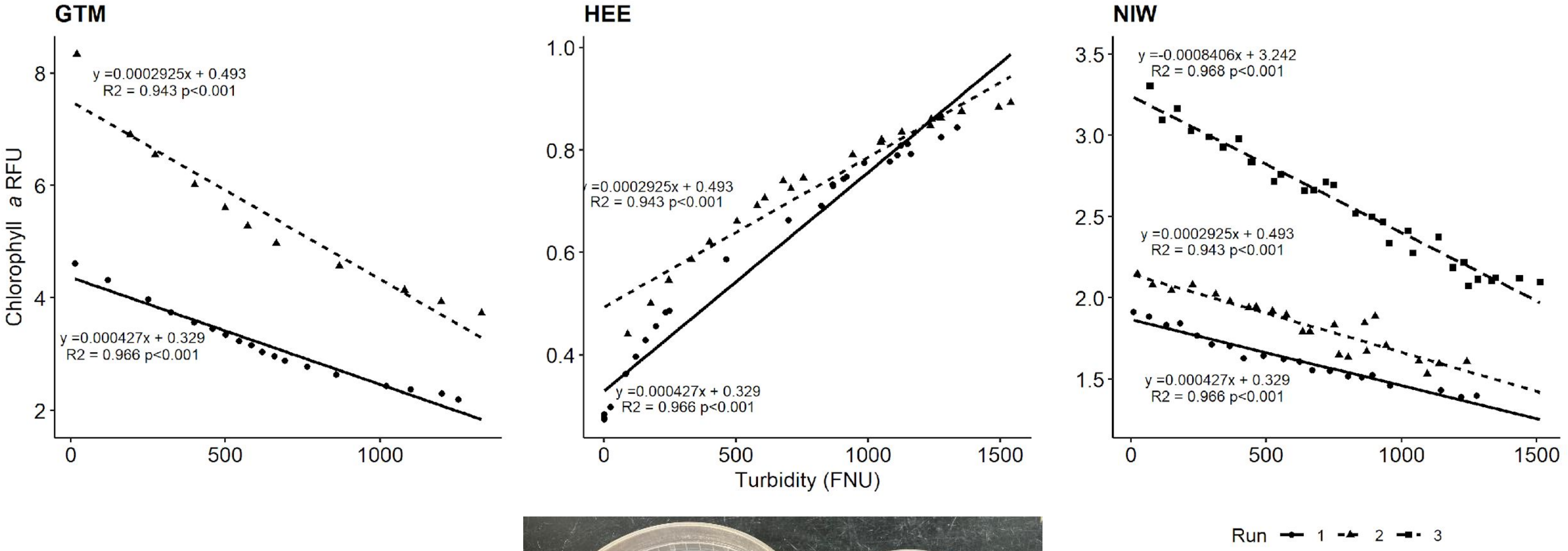


FDOM experiment at Lake Superior

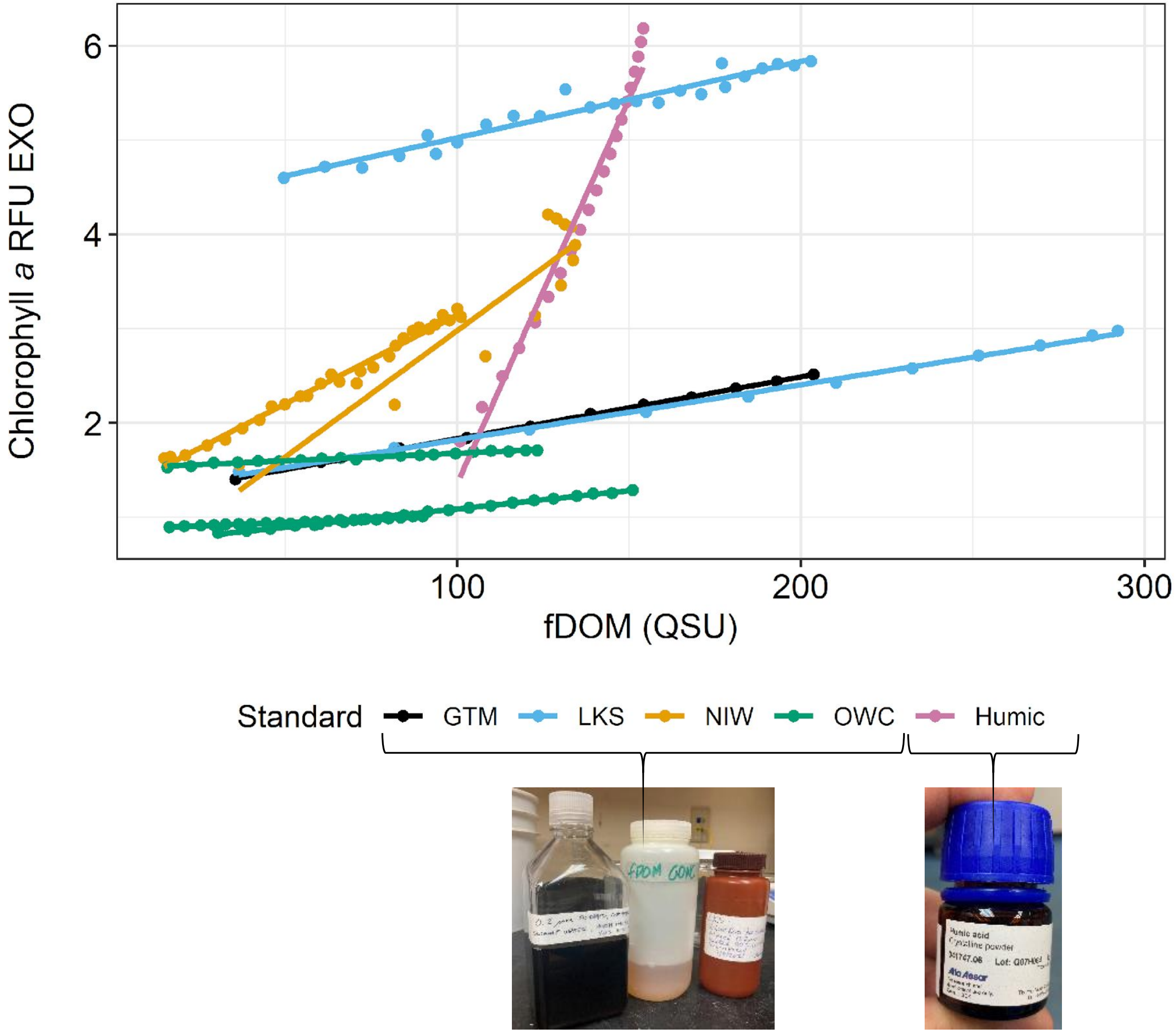
Turbidity standard

FDOM standards

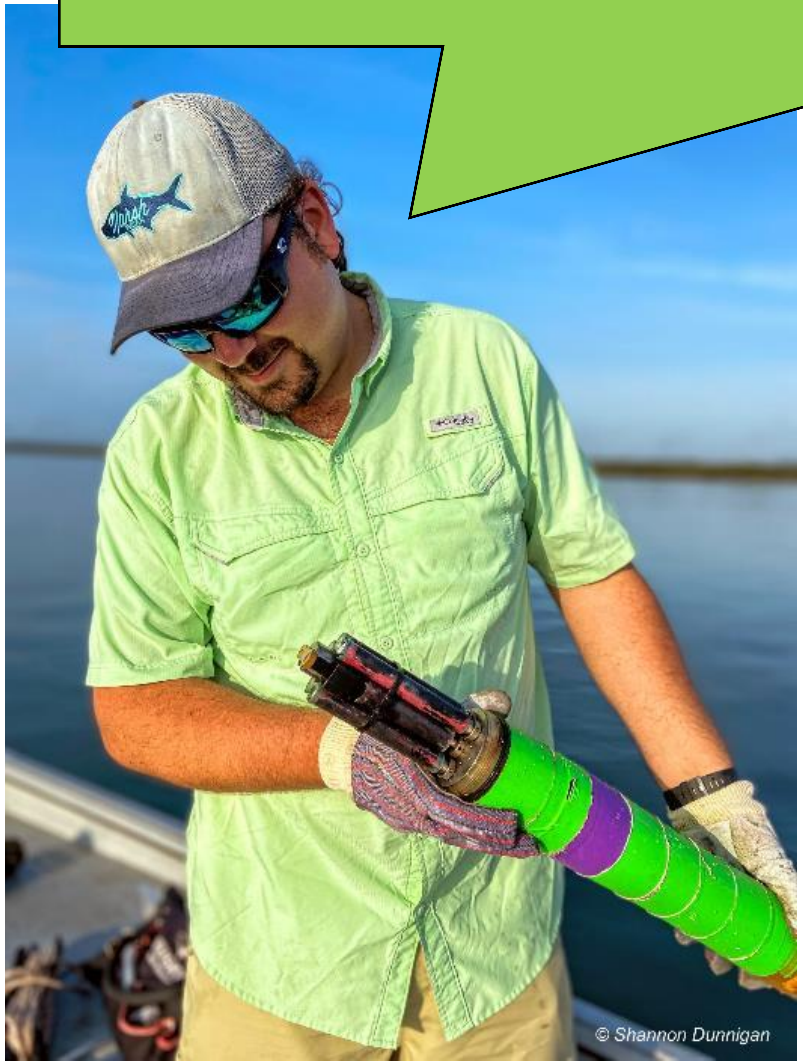
Results – Turbidity Effect



Results – 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

Heʻeia

Padilla Bay

Wells

Methods – Lab-Based Comparisons

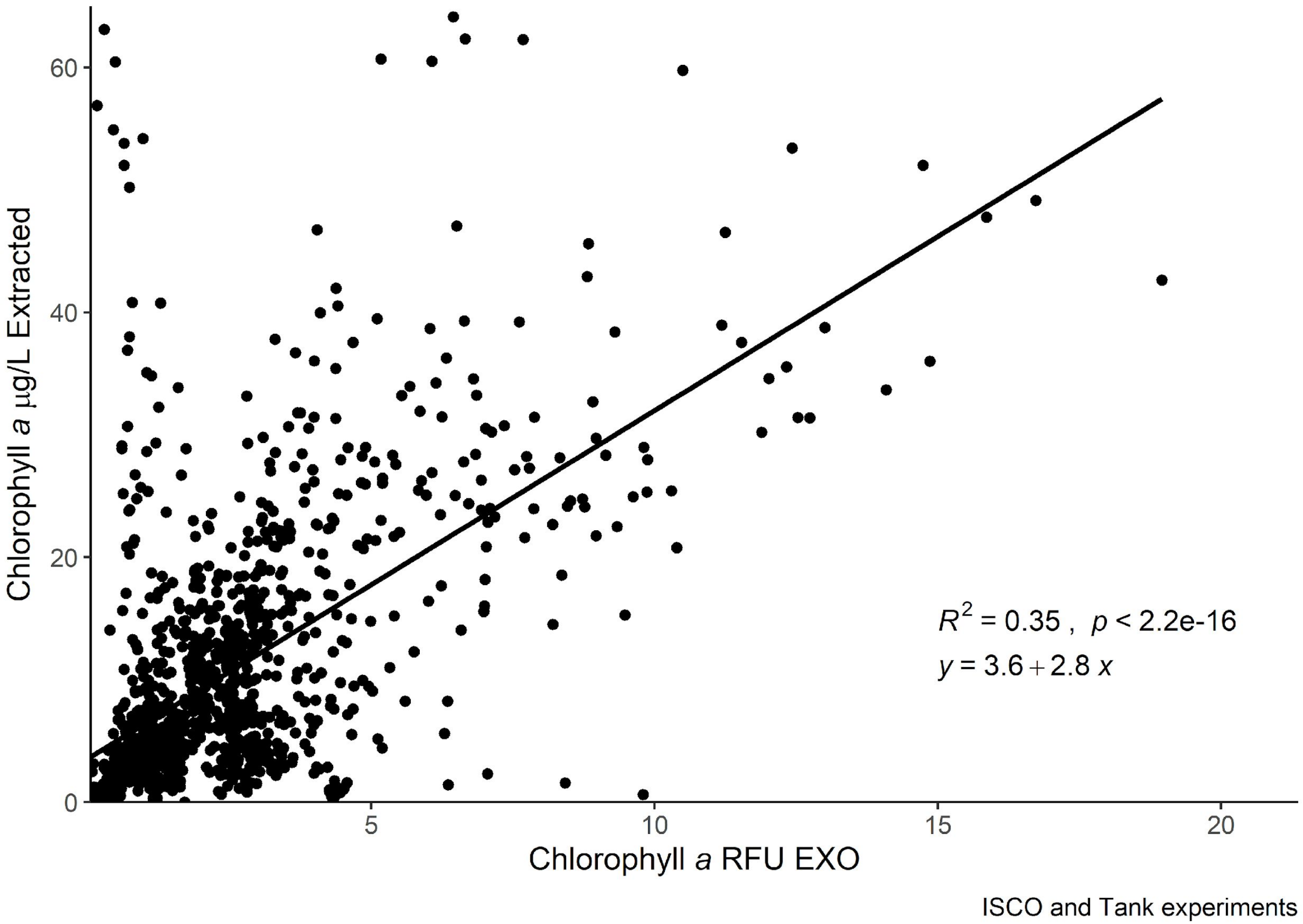
GTM

North Inlet

Heʽeia

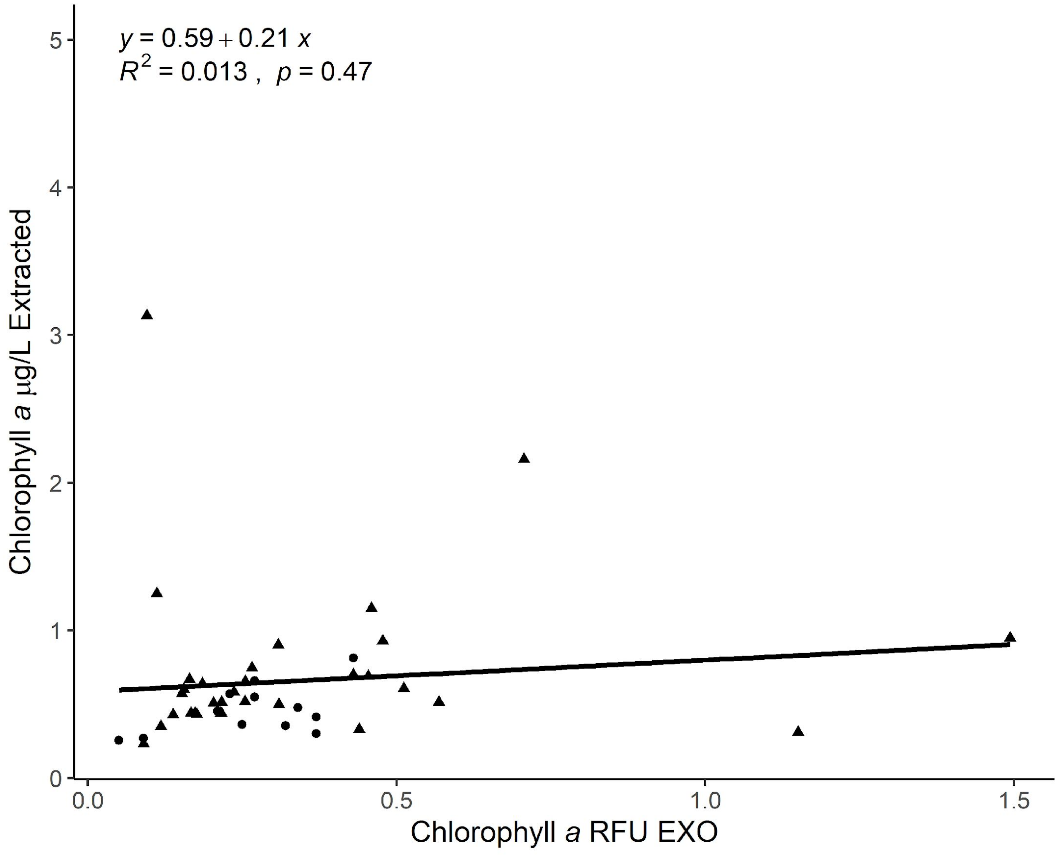
Mission Aransas

Results - Comparisons

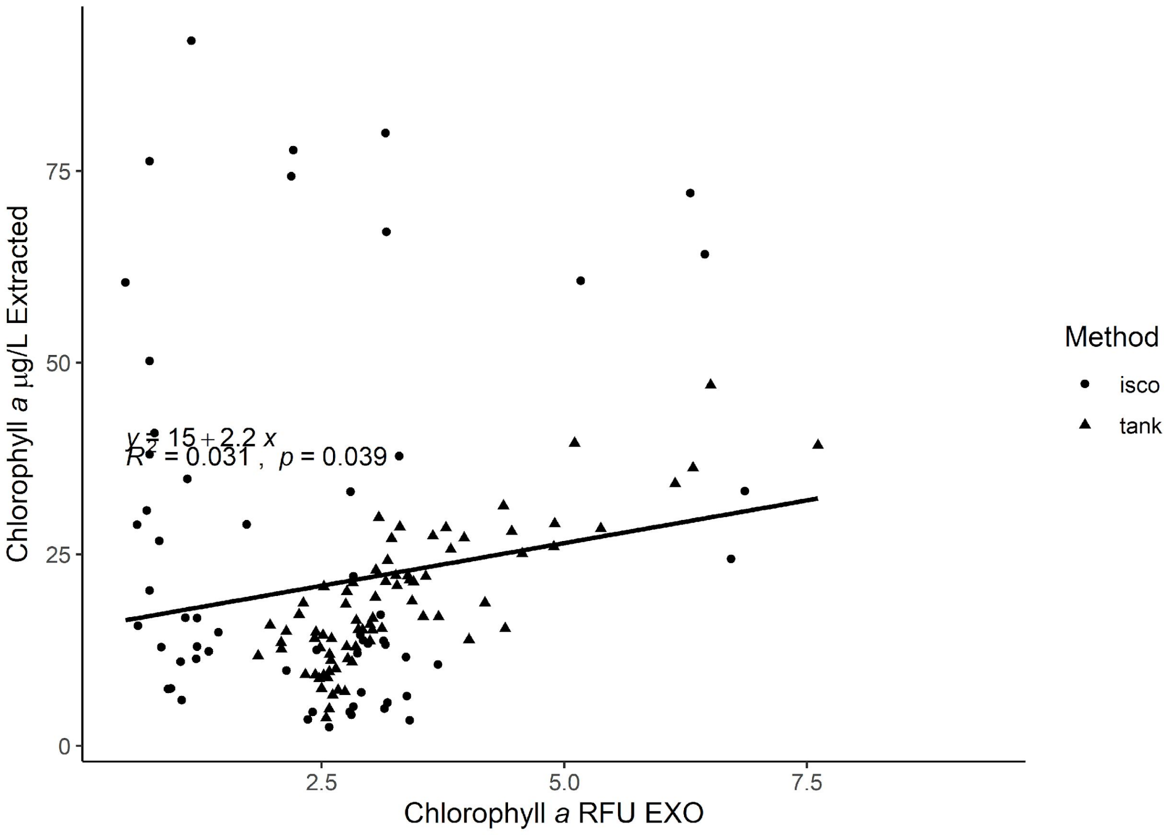


Results - Comparisons

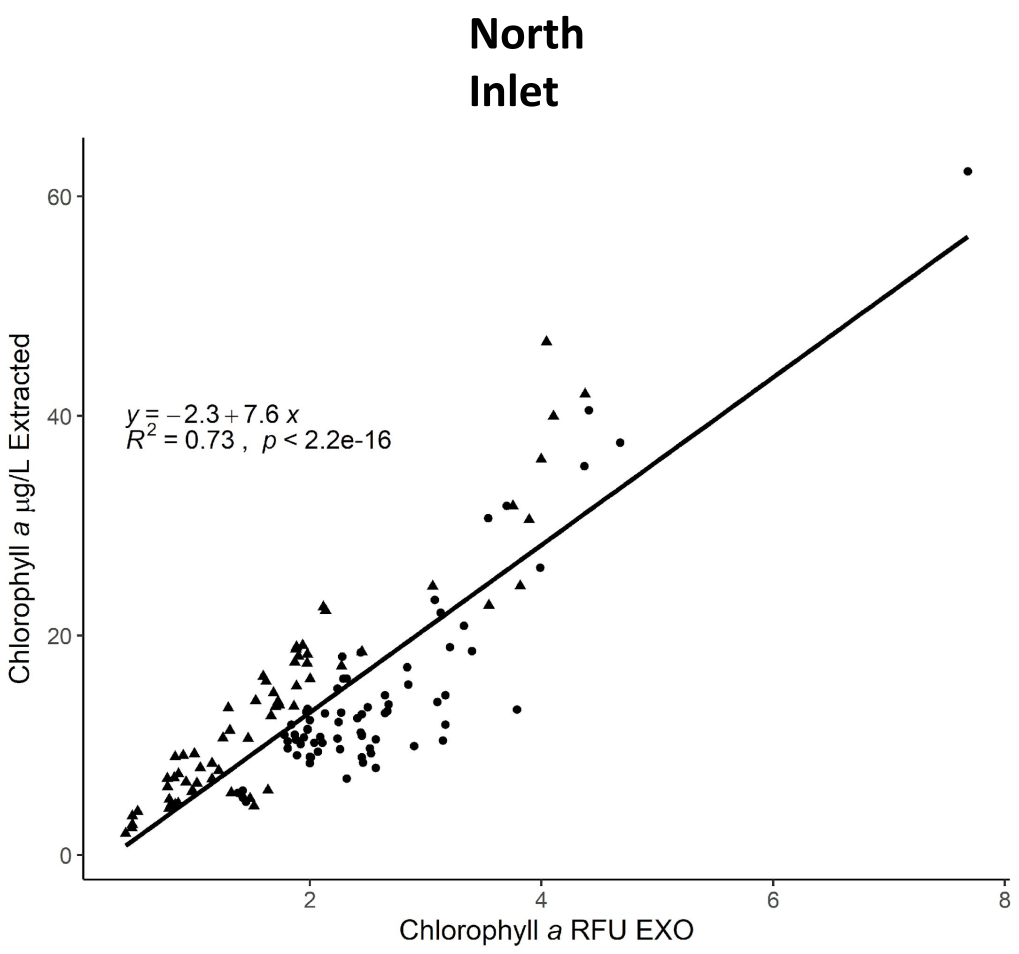
He'e
ia

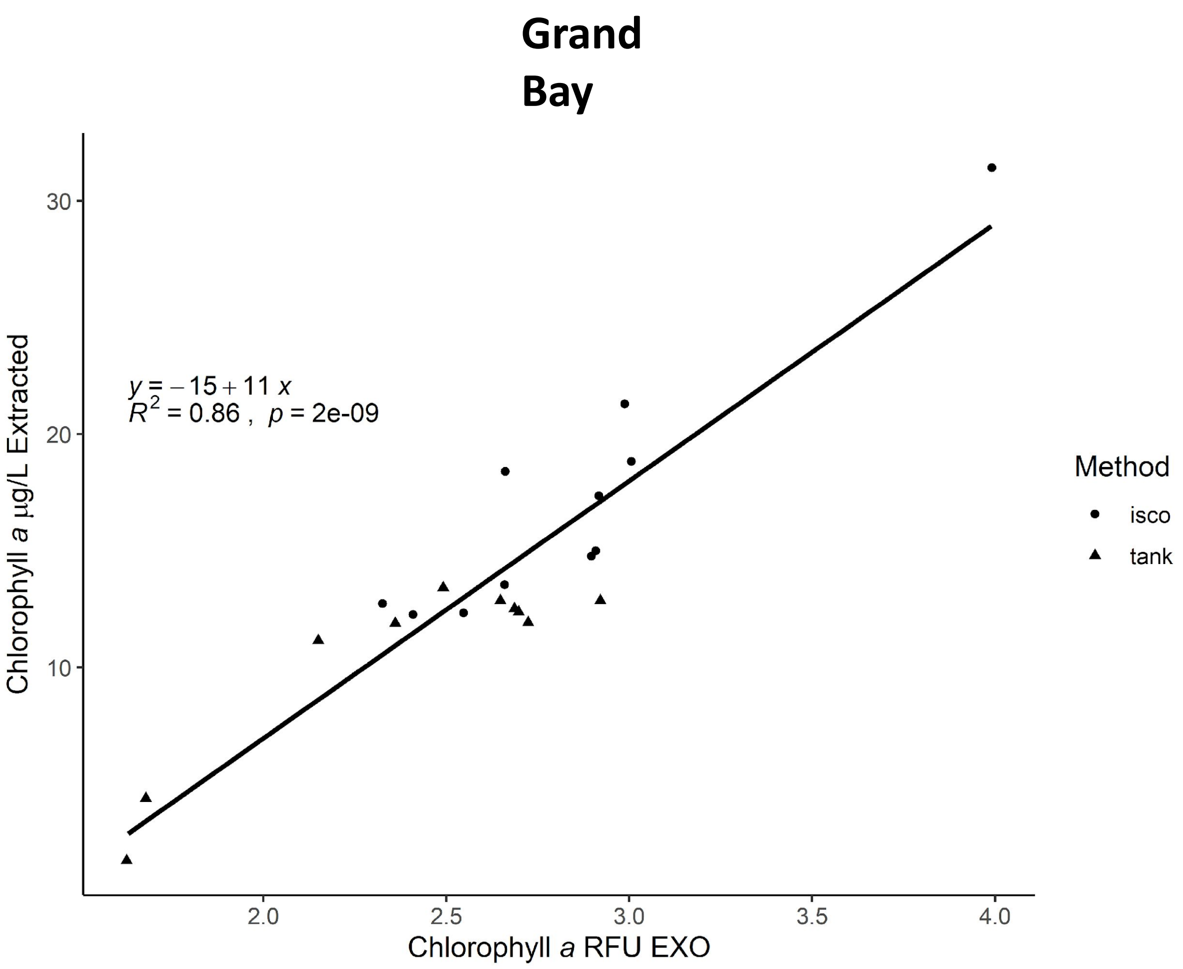


Lake
Superior



Results - Comparisons





Methods – Data Analysis

Main question

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

Models

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

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

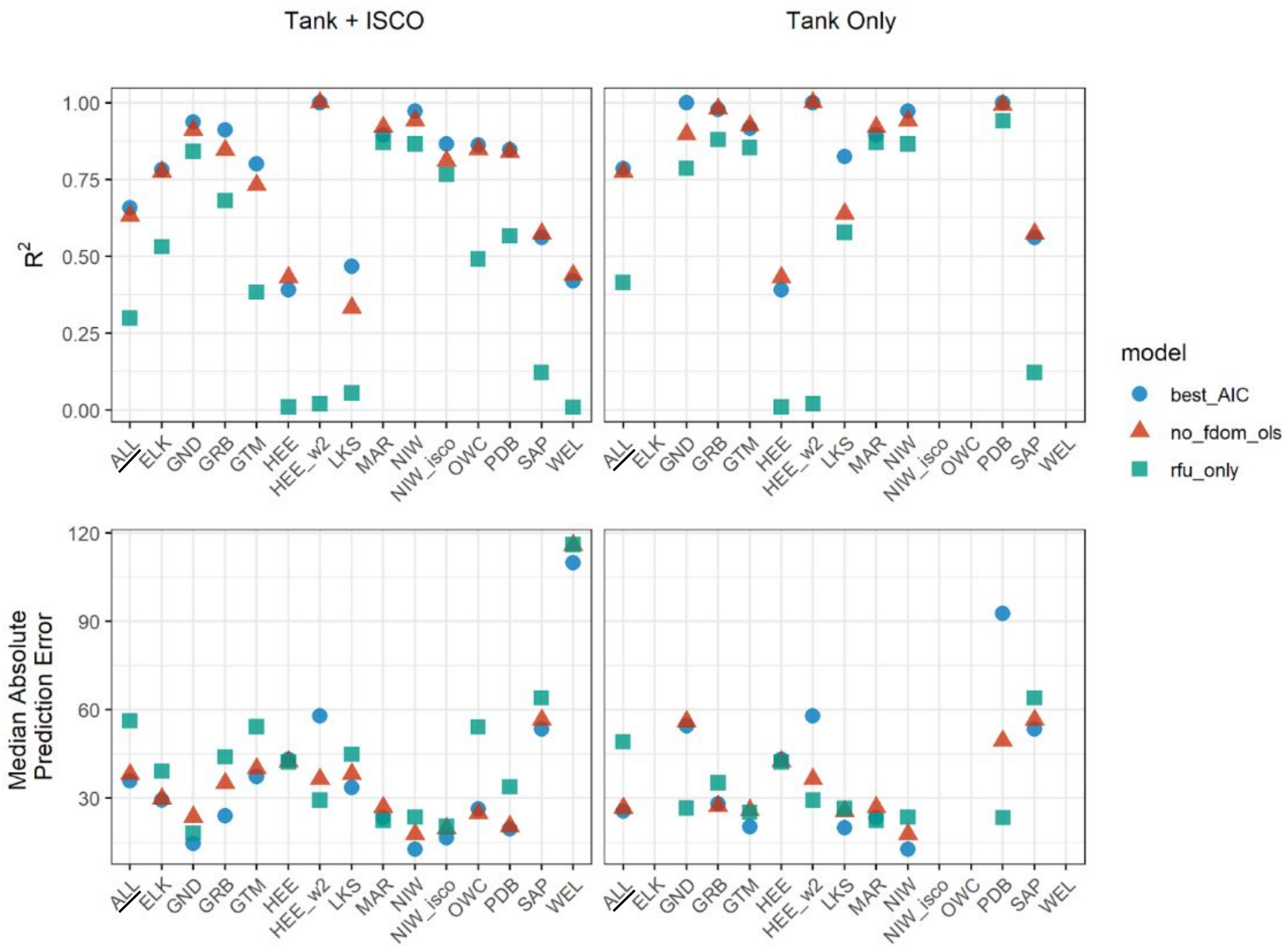
- Square root transformation
- AICc to pick "best" model

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

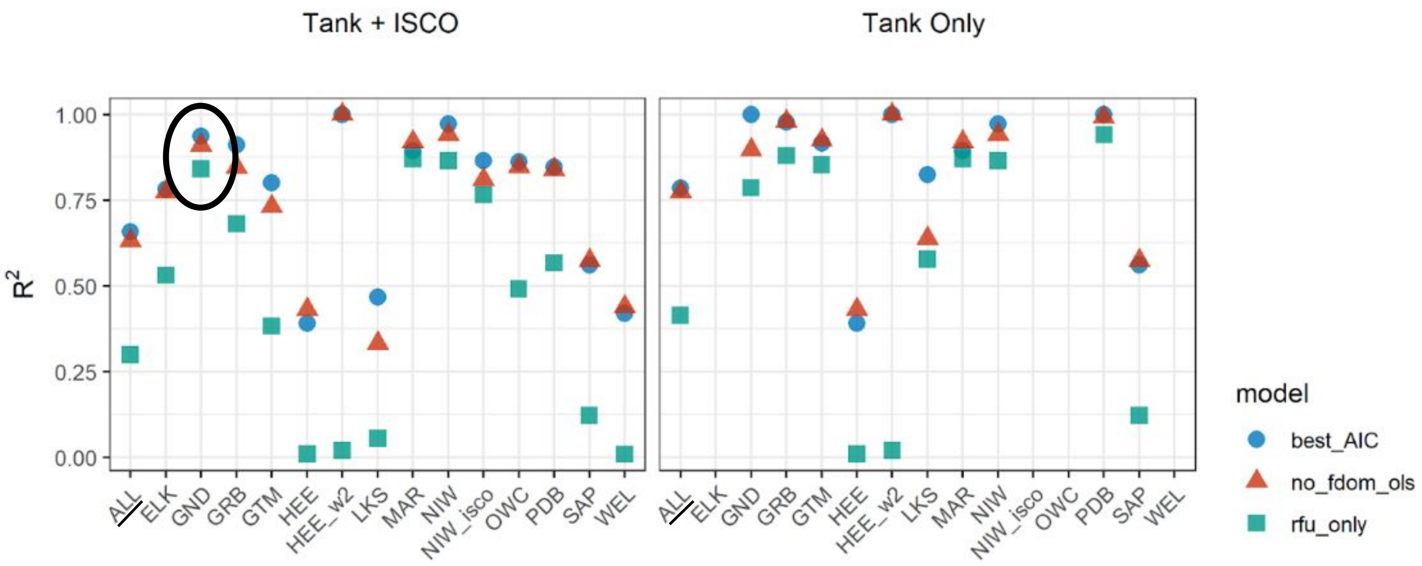


Full model, best AICc

Full model without FDOM

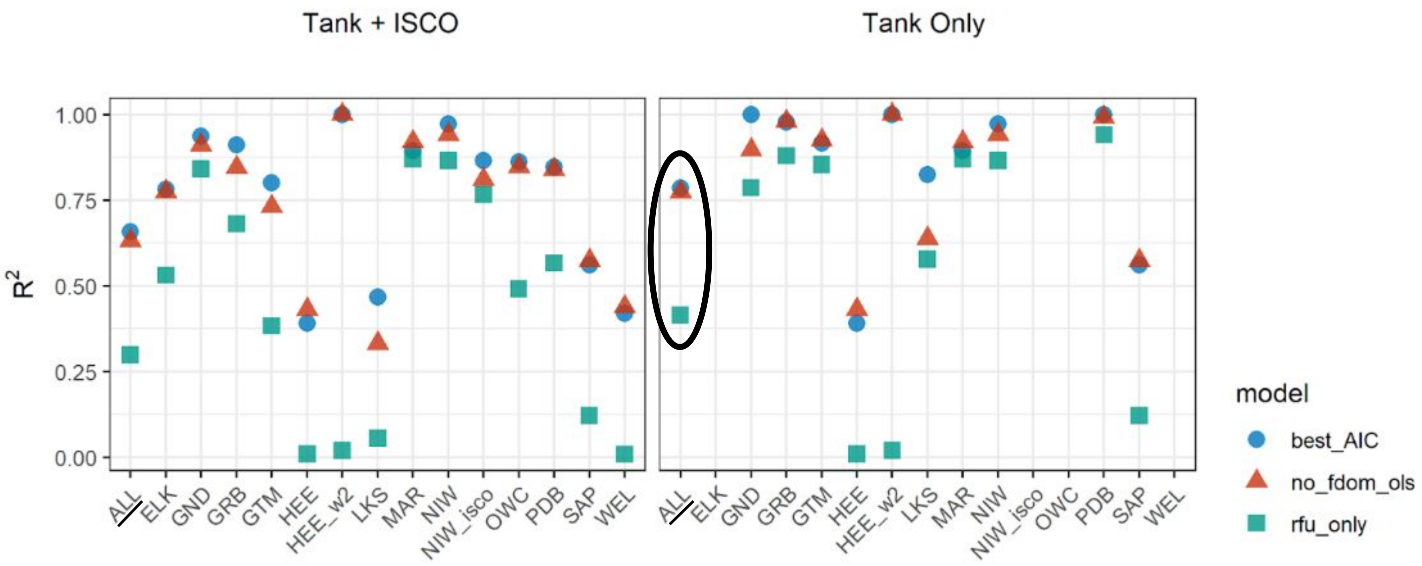
RFU only

Results – Data Analysis



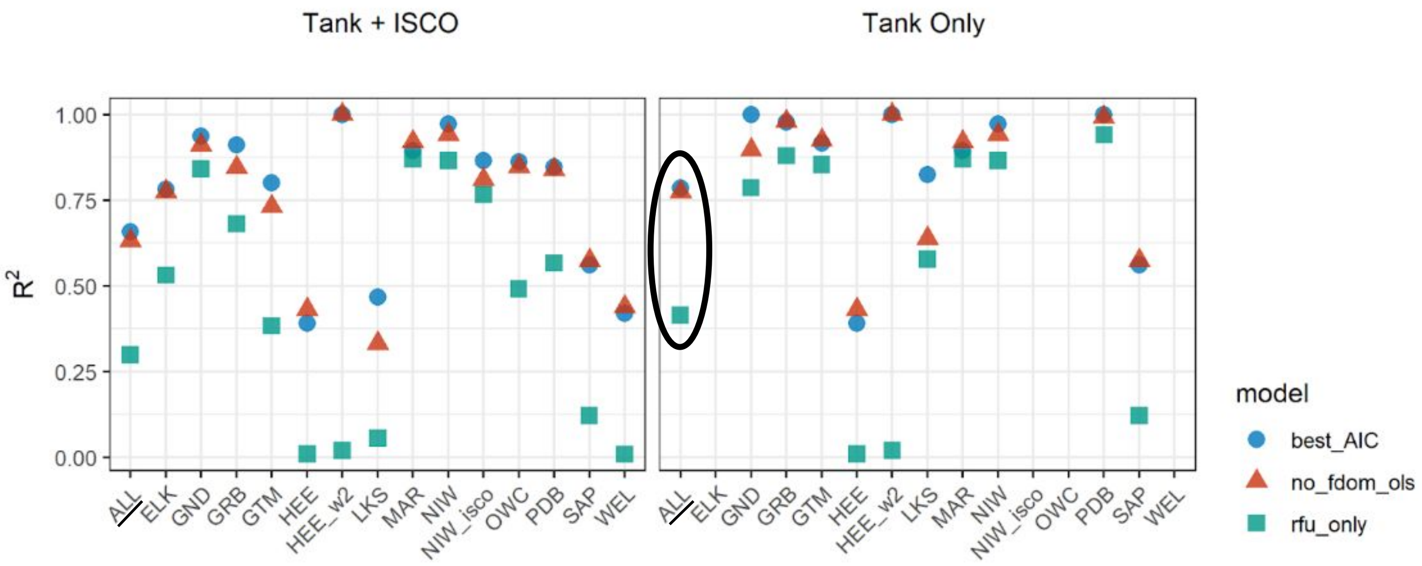
Reserve	model	R.2	prediction_ error	sensor_rfu	fdom_qsu	turb	season	temp	X.Intercept .	fdom_qsu. sensor_rfu	fdom_qsu.t emp	fdom_qsu.t urb	sensor_rfu. temp	sensor_rfu. turb	fdom_qsu. sensor_rfu. turb
ELK	best_AIC	0.782	29.3	0.365	0.0242	-0.0201	+	0.2324	-1.216	-0.012	NA	NA	NA	NA	NA
ELK	no_fdom_ols	0.775	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

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



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

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 40% of the variance in extracted CHL-A. Predictive capability increased when other sensor 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.

Project Page

https://nerrssciencecollaborative.org/project/Dix20

National Estuarine Research Reserves
Science Collaborative

Webinar
April 19 @ 3:30

https://nerrssciencecollaborative.org/webinar-series

Contact me:
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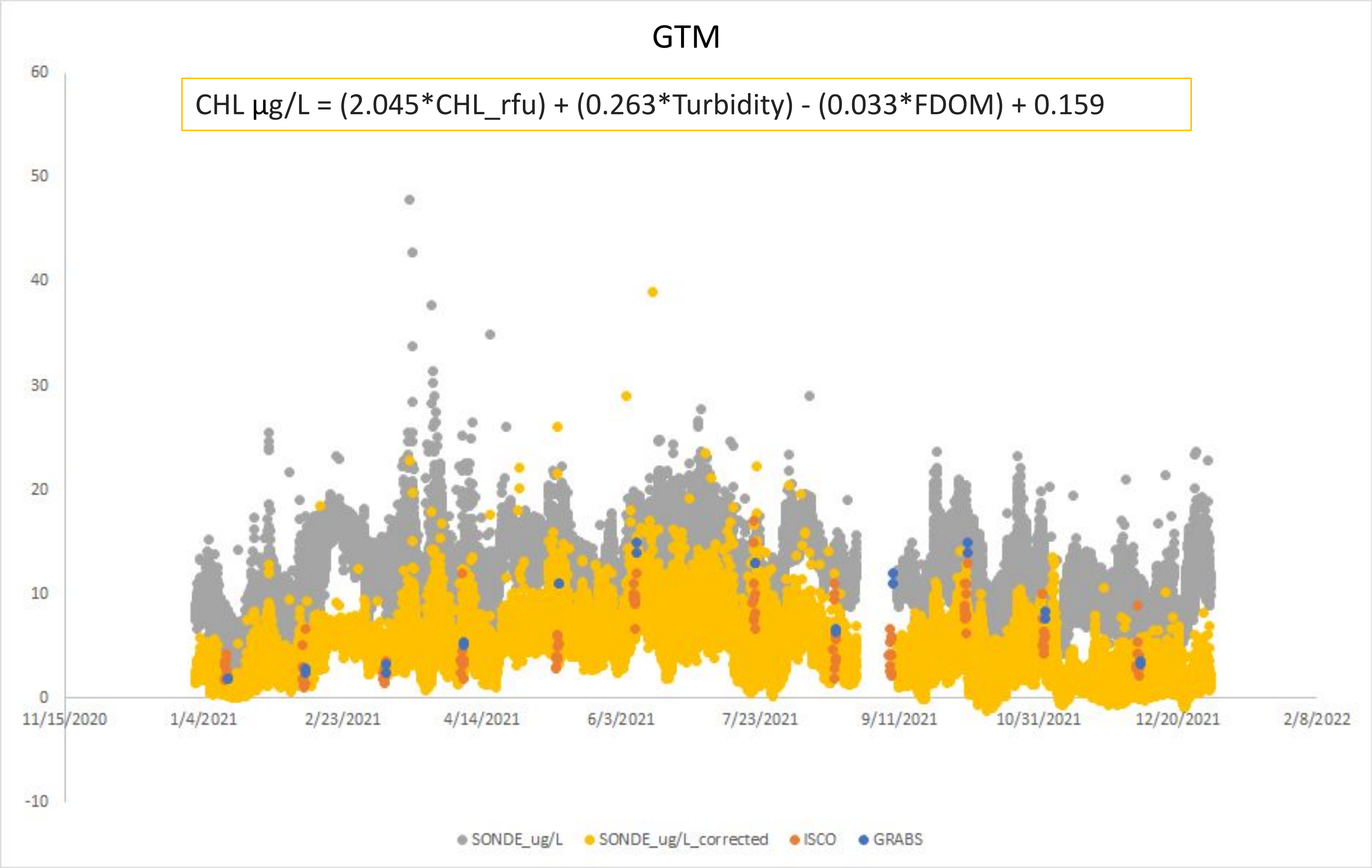
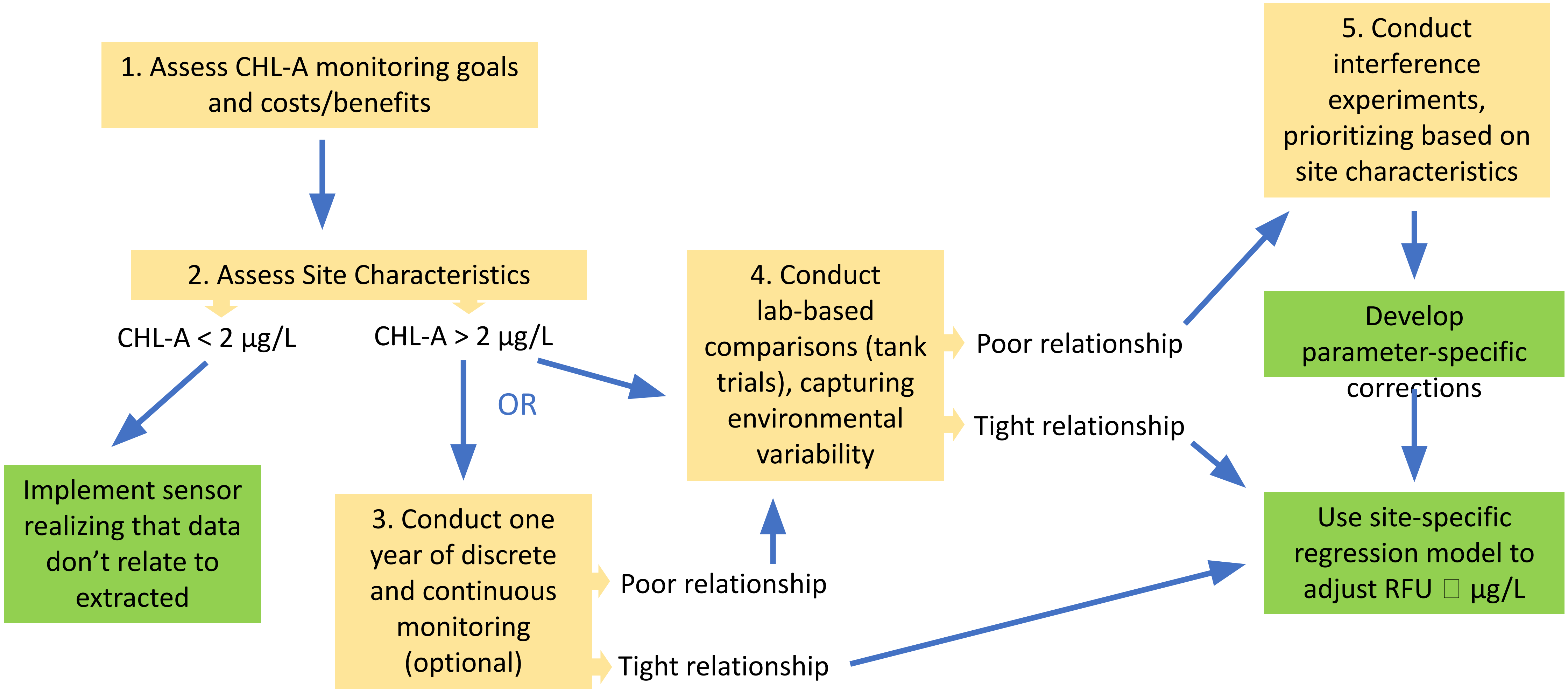
Camille Wheeler
poster #19
Using Chlorophyll fluorescence sensors to investigate temporal dynamics in two contrasting ecosystems in the North Inlet-Winyah Bay National Estuarine Research Reserve

Adjustment Example



Recommendations



Considerations

- All CHL-A methods have caveats about 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 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

Results – Temperature Effect

NIW