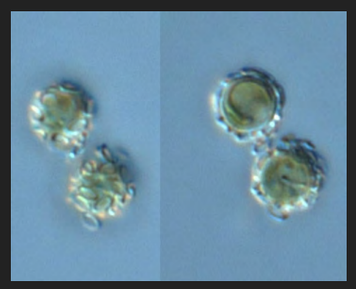
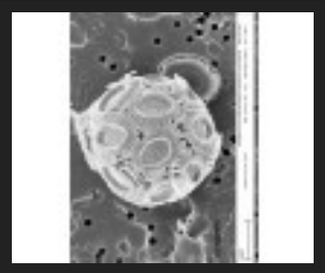
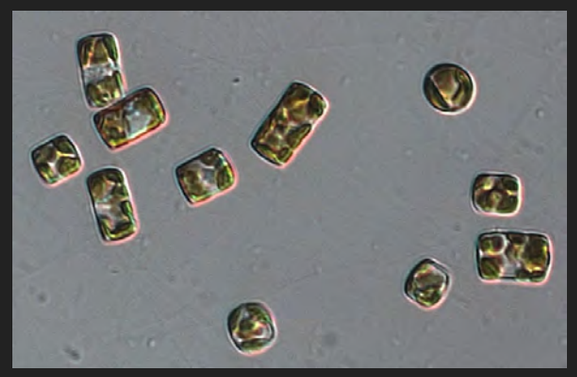
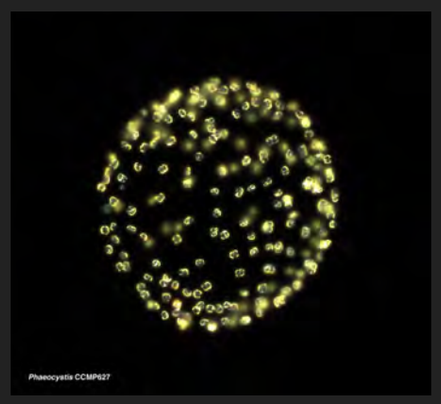








Antonio Mannino, Ryan Vandermeulen, Aimee Neeley, and Michael Lomas

Optical and Pigment Phytoplankton Hyperspectral Library

Supported by the NASA OBB Program

OUTLINE

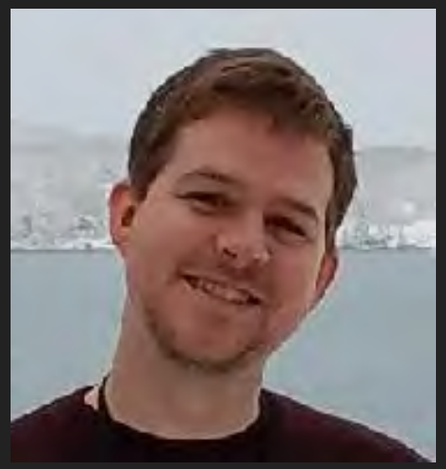
- Motivation
- Team
- Approaches to Libraries for PFTs/Phytoplankton Community Composition
- Overview of Experiments
- Experimental Setup and Measurements Collected
- Preliminary Results: absorption, attenuation & backscatter
- Future Work

TEAM MEMBERS & KEY CONTRIBUTORS

Mike Lomas (PI)

A. Neeley (co-I)

R. Vandermeulen (co-I)



Antonio (co-PI)

J. Blanchette

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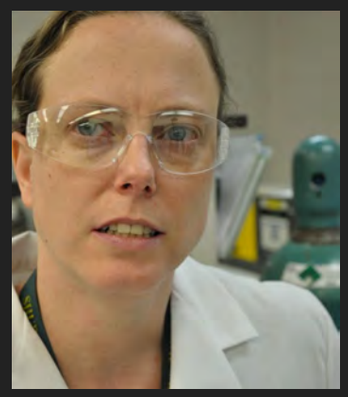
S. Freeman

G. Kim

C. Thomas



P. Lange

MOTIVATION

- **GOAL:** Enable characterization of how climate change alters phytoplankton communities as these changes will impact both carbon export from the surface ocean and the flow of carbon to higher trophic levels.
- **Objective**
  - Develop and apply optical-biogeochemical libraries for identification of phytoplankton communities from Remote Sensing and *in situ* times series of optical and pigment databases.
- **Research Questions**
  - What are the impacts of climate change on phytoplankton community composition and total biomass?
  - Do patterns in direct observations of PFTs (e.g., HPLC pigment-derived, flow cytometrically and microscopically enumerated phytoplankton) concur with satellite derived PFT estimates across regions with different physical and biological gradients?
  - How do the spectral fingerprints of PFTs change, and therefore our ability to quantify PFTs, in response to climate change variables?

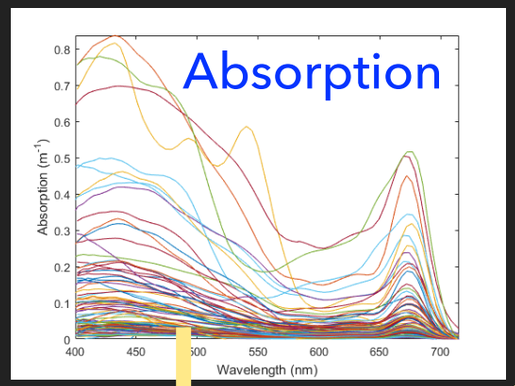
PHYTOPLANKTON STUDIED BY TAXONOMY & DISTRIBUTION

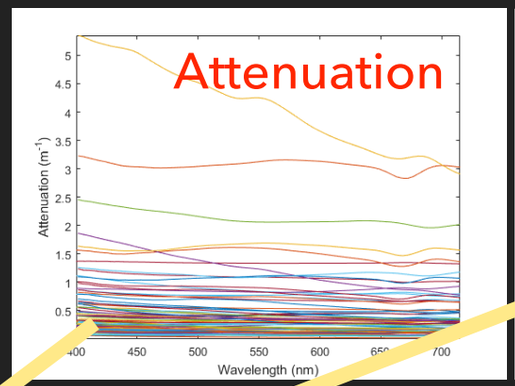
~PFT	Polar	Temperate	Sub/Tropical	Mixtures
Diatoms	15	7	1	5
Cyanobacteria			4	4
Coccolithophores		4	1	4
Chlorophytes			2	2
Pelagophytes		1	1	2
Dinoflagellates	1	2	3	
Prasinophytes			2	
Cryptophytes			1	
Stramenopiles		1		
Phaeocystis	1	1		
other Prymnesioph.		3	1	
Pico-plankton	0	1	5	
Nano-plankton	4	7	16	
Micro-plankton	13	2	4	

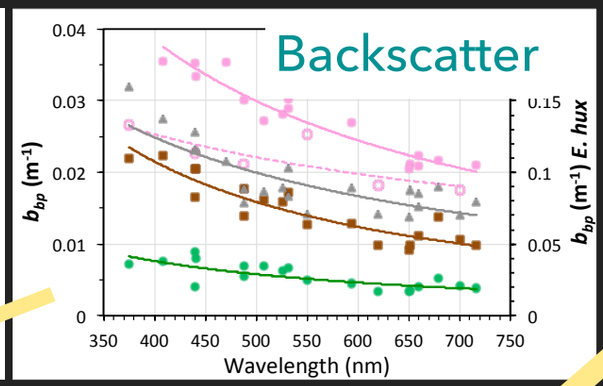
Excludes Evolution & Co-Habitation experiments (3 species & 3 mixtures, respectively)

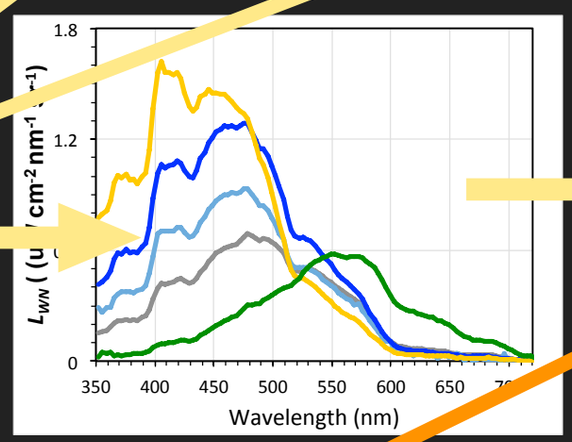
APPROACHES FOR PFT / COMMUNITY COMPOSITION

I. Phytoplankton (hyper)-Spectral Library



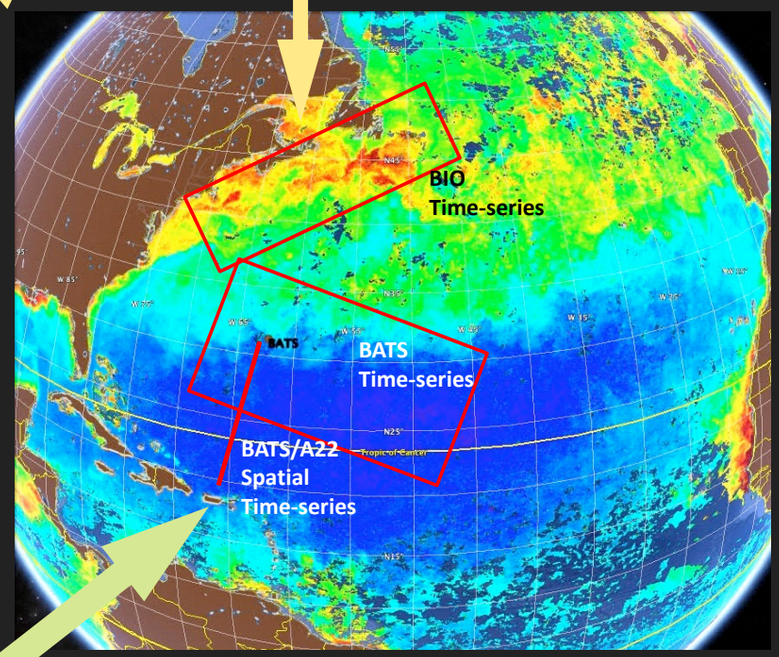






OPTICAL–BIOGEOCHEMICAL–ALLOMETRIC DATABASE

REMOTE SENSING PFTs & COMMUNITY COMPOSITION ALGORITHMS



II. CHEMTAX Biomass-based Library

Pigments, C/N, #, size

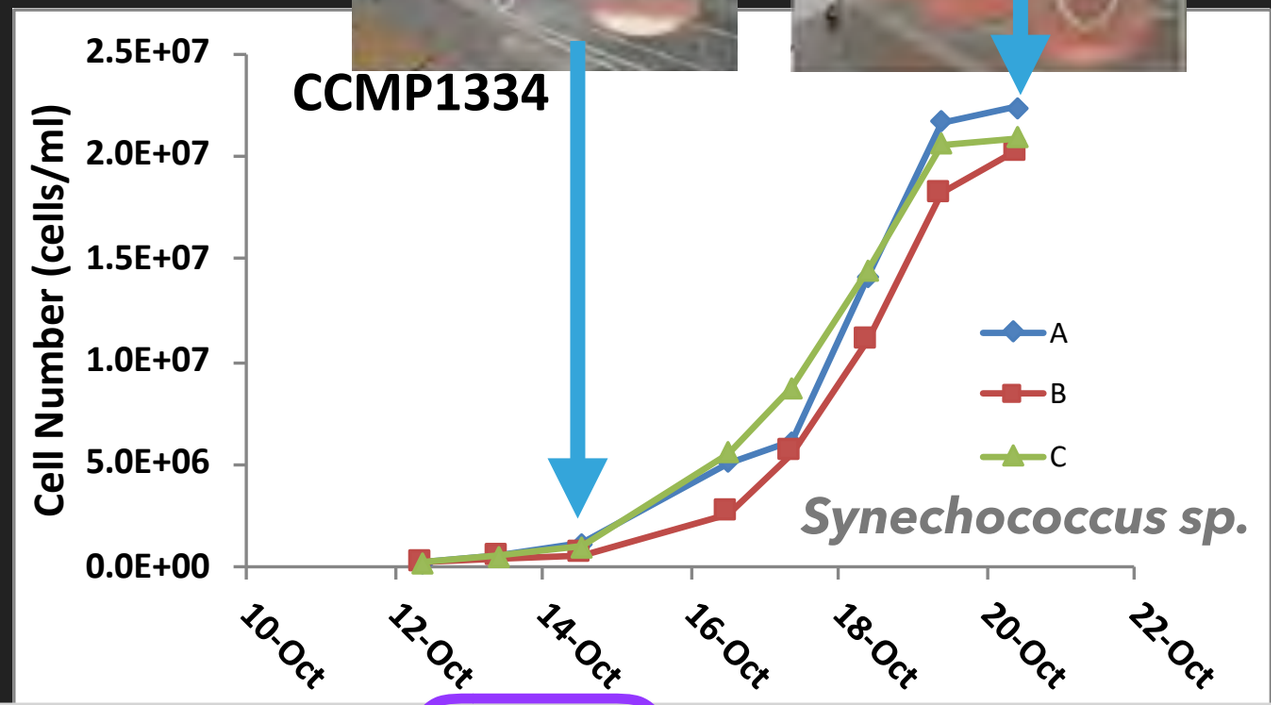
CHEMTAX-REV DATABASE

PFTs & COMMUNITY COMPOSITION ALGORITHMS

Multi-Decade PFT & Phytoplankton community dataset for climate change/ trend analysis

EXPERIMENTS

- Axenic stock cultures
- Measurements at
  - Exponential growth
  - Stationary growth
- Individual species (~55)
- Climate Change Manipulations (CC)
  - +CO_2, +Temp, +Light
- Radiometry
- Mixtures of species
- Co-Habitation
- Adaptation



		Mix #1	Mix #2	Mix #3	Mix #4	Mix #5	Mix #6	Mix #7	Mix #8	CC	Rrs SAS	Evolution
Diatoms												
CCMP1316	*Chaetoceros muelleri (24 ℃)*											
CCMP988	*Thalassiosira guillardii (14 ℃)*											
CCMP1005	*Thalassiosira oceanica (20 ℃)*											
3 isolates	*Ditylum brightwelli (14/20 ℃)*											
"Flagellates"												
CCMP1194	*Prasinococcus capsulatus (20 ℃)*											
CCMP908	*Tetraselmis sp. (24 ℃)*											
CCMP1756	*Pelagomonas calceolate (24 ℃)*											
CCMP3430	*Ostreococcus lucimarinus (20 ℃)*											
Coccolithophores												
CCMP1949	*Emiliania huxleyi (14 ℃)*											
CCMP647	*Pleurochrysis carterae (14 ℃)*											
CCMP373	*Emiliania huxleyi (20 ℃)*											
CCMP371	*Emiliania Huxleyi (20 ℃)*											
CCMP298	*Cruciplacolithus sp. (24 ℃)*											
Cyanobacteria												
CCMP2389	*Prochlorococcus marinus (24 ℃)*											
CCMP1334	*Synechoccoccus* sp. (24 ℃)											
Dinoflagellates												
2 isolates	*Amphidinium (20/24 ℃)*											
4 isolates	*Heterosigma akashiwo (14/20 ℃)*											

EXPERIMENTAL SETUP AND MEASUREMENTS

Preparation of Stock Cultures

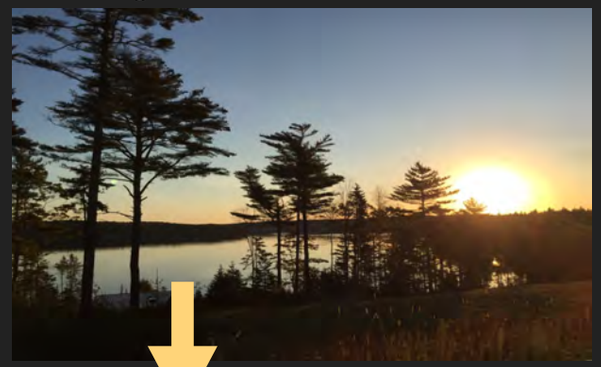
Stock Culture

Cell Counts

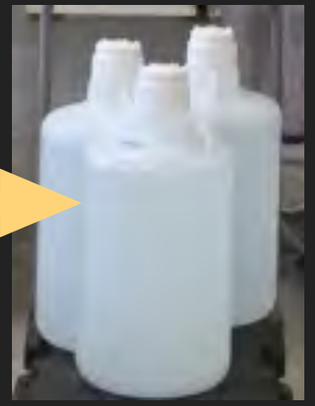
(Flow Cytometry & Light Microscopy)

EXPERIMENTAL SETUP AND MEASUREMENTS

Salty River Water



Filtered & Measured



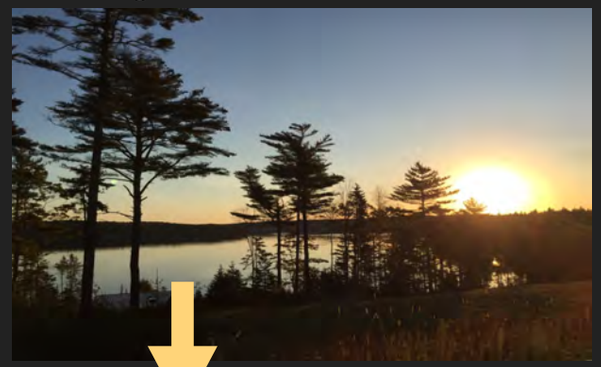
Stock Culture

Cell Counts

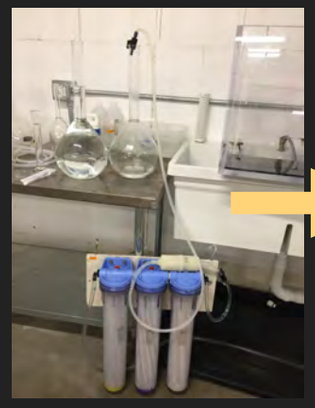
(Flow Cytometry & Light Microscopy)

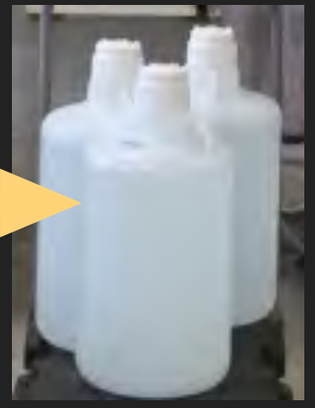
EXPERIMENTAL SETUP AND MEASUREMENTS

Salty River Water



Filtered & Measured





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Stock Culture

=

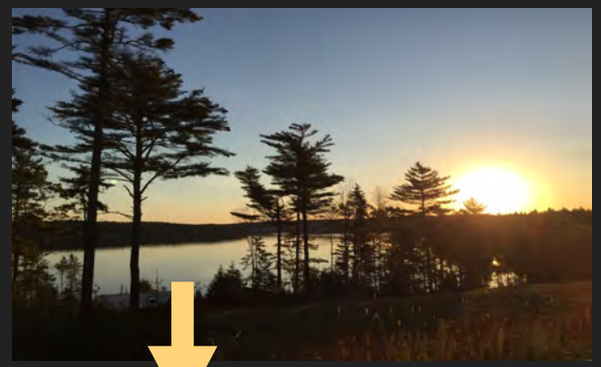
Measured & Stirred

Natural Phytoplankton Bloom Cell Concentrations

Cell Counts

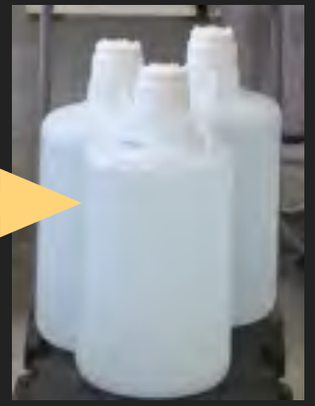
(Flow Cytometry & Light Microscopy)

EXPERIMENTAL SETUP AND MEASUREMENTS



Filter Samples

Pigments
POC/PN
PIC, POP,
a_p, a_d , a_g,
nutrients,
DOC, etc.



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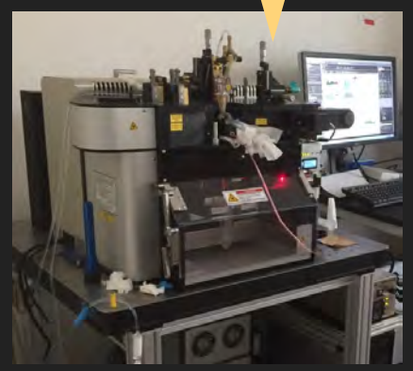
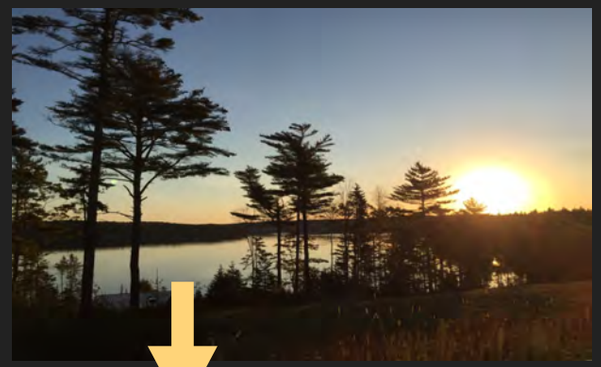
Cell Counts,
Size, Biovolume



(Flow Cytometry &
Light Microscopy)

EXPERIMENTAL SETUP AND MEASUREMENTS



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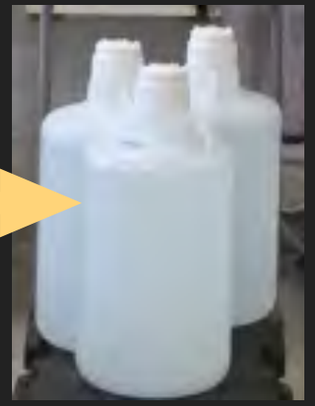

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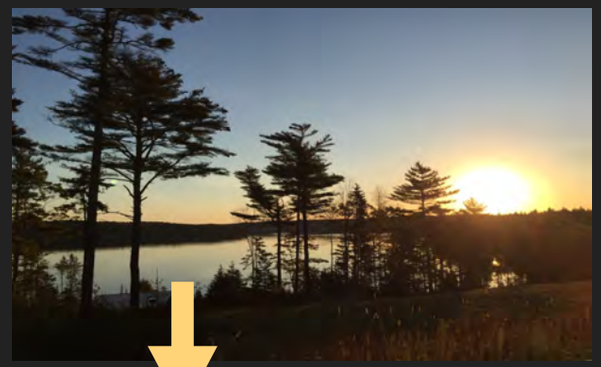
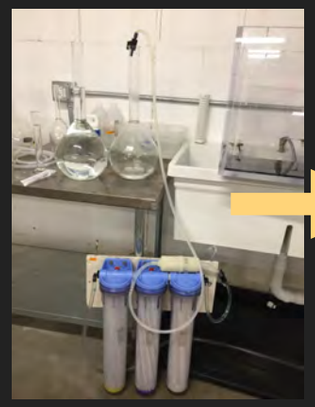
Cell Counts,
Size, Biovolume

(Flow Cytometry &
Light Microscopy)

Particle Absorption
(IS Mode)

EXPERIMENTAL SETUP AND MEASUREMENTS





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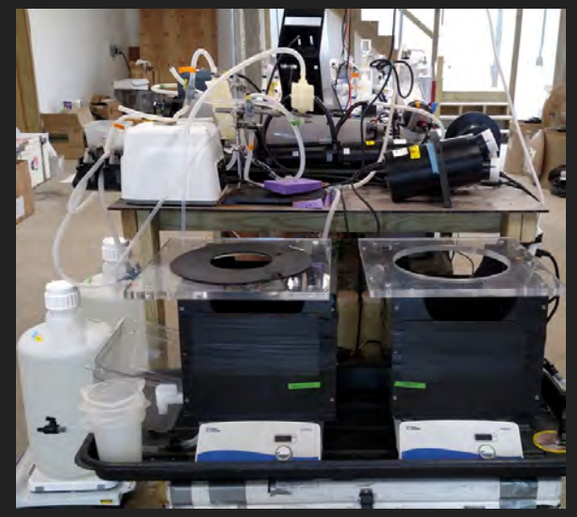
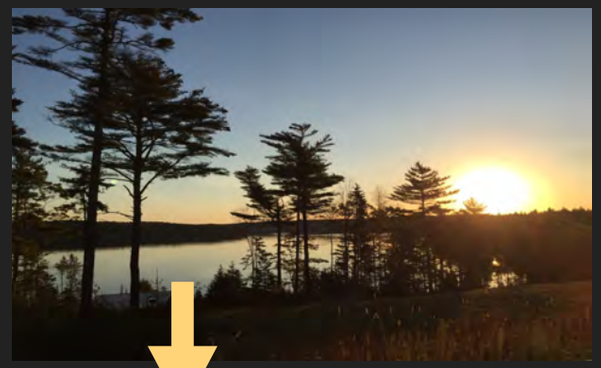


Backscatter
(VSF-3, HS6, BB9)

Flow-Through IOPs
(ac-s, PhytoFlash, TSG, ICAM, BB3, VSF-R) and LISST

Processed
- Whole Water
- <0.2 µm Water

EXPERIMENTAL SETUP AND MEASUREMENTS



Pigments
POC/PN
PIC, POP,
a_p, a_d , a_g,
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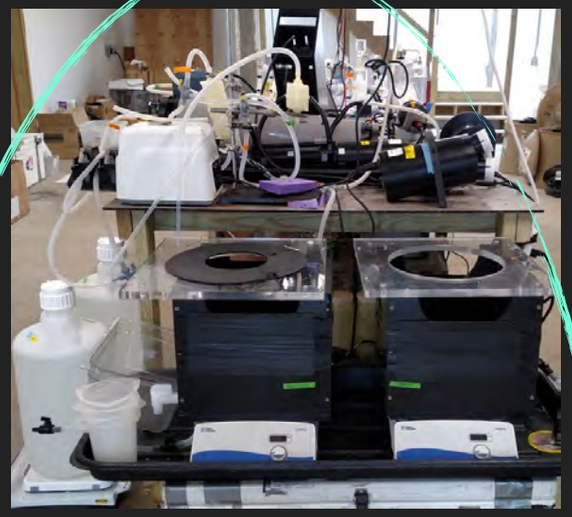
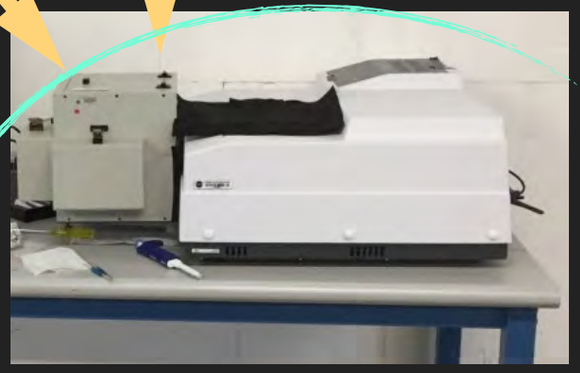


Backscatter
(VSF-3, HS6, BB9)

Flow-Through IOPs
(ac-s, PhytoFlash, TSG,
ICAM, BB3, VSF-R) and LISST

Cell Counts,
Size, Biovolume

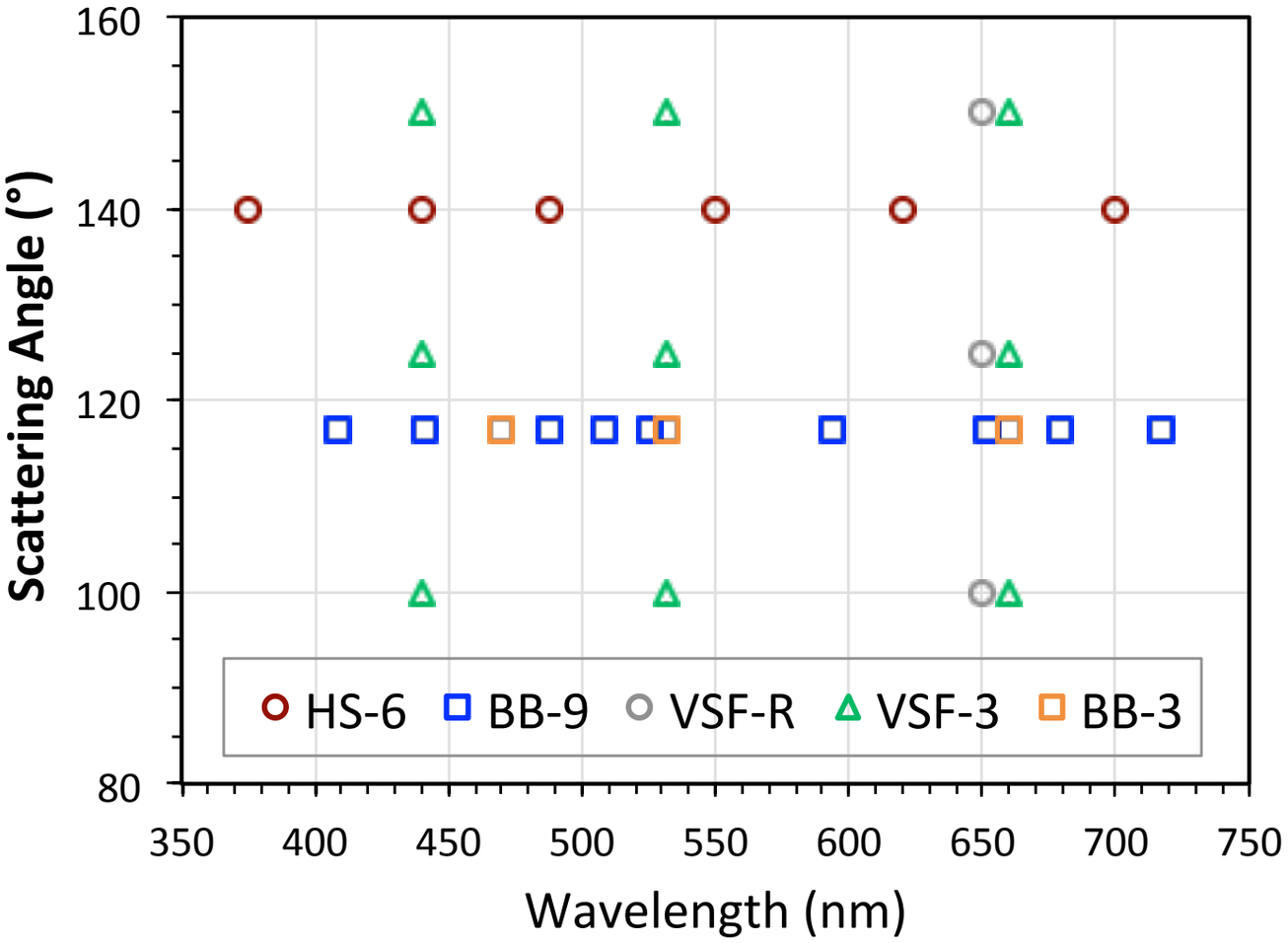
(Flow Cytometry &
Light Microscopy)



Particle Absorption
(IS Mode)

SPECTRAL AND ANGULAR DETAILS FROM SCATTERING SENSORS

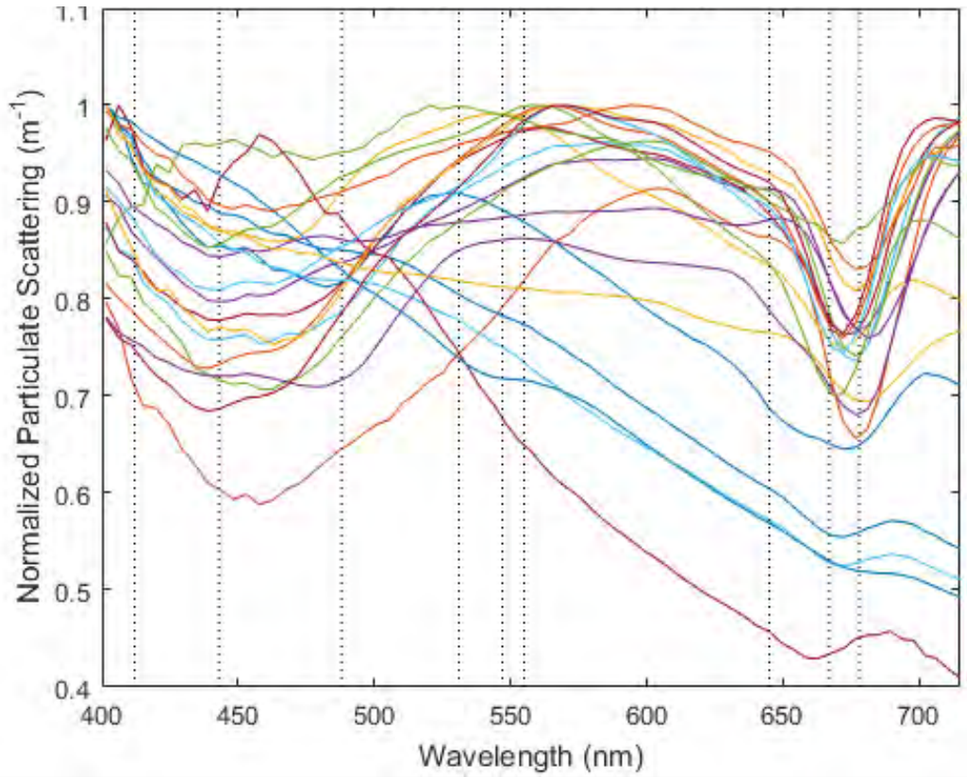
b_{bp} from VSF-3, VSF-R, BB3, BB9 and HS6



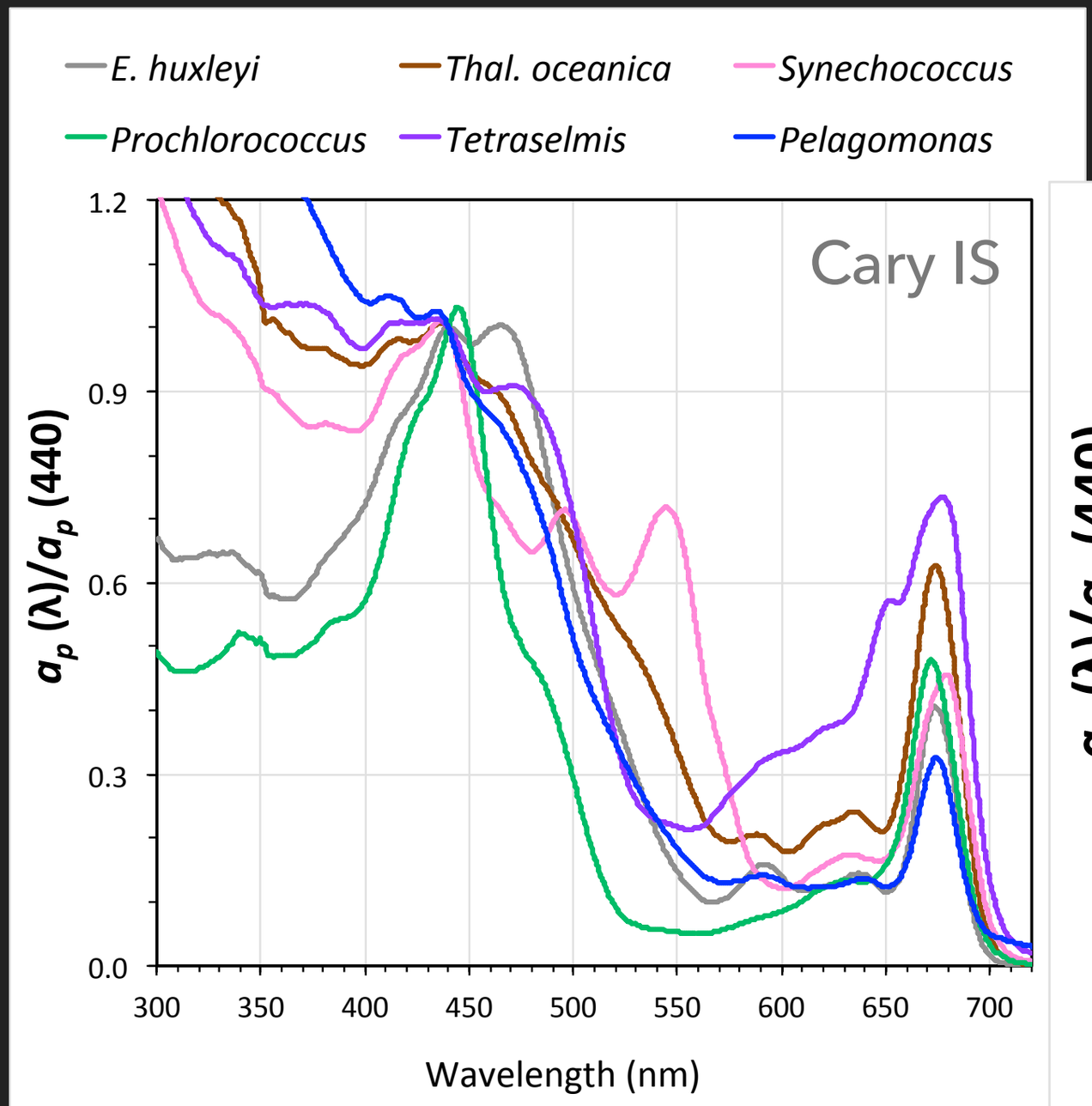
16 discrete wavelengths

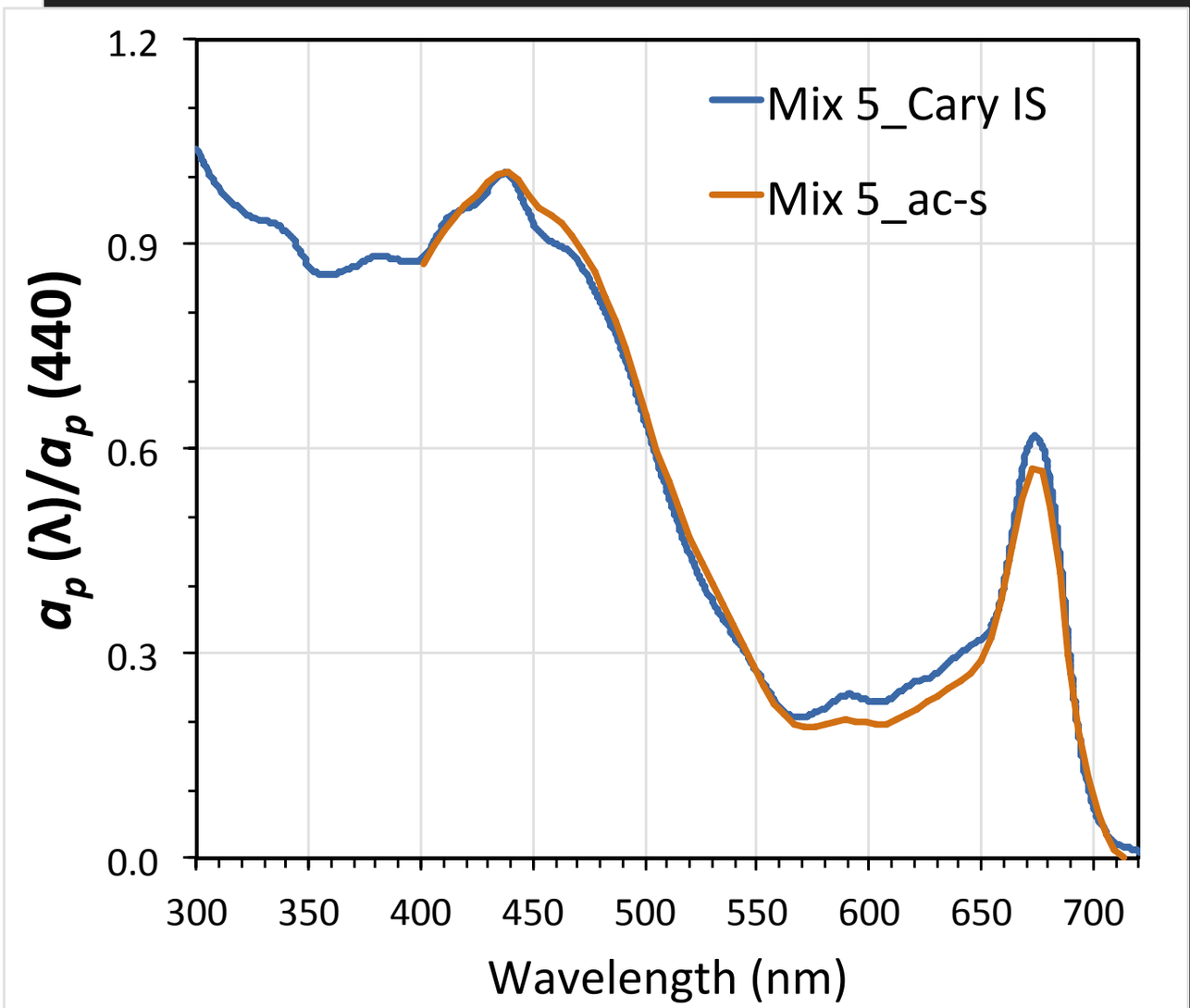
5 unique angles

Scattering coefficient (b) from ac-s



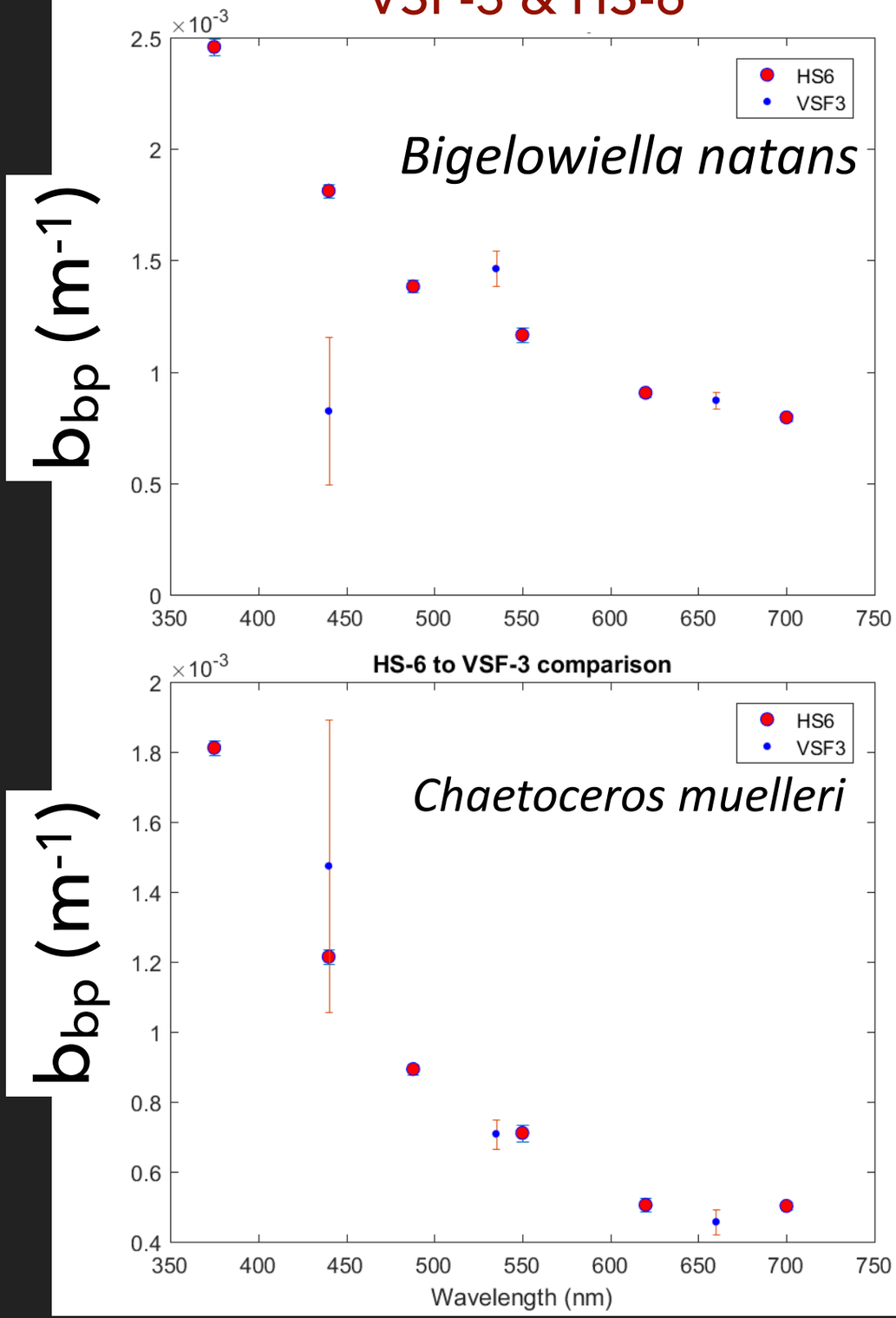
PHYTOPLANKTON ABSORPTION – INDIVIDUALS & MIX 5



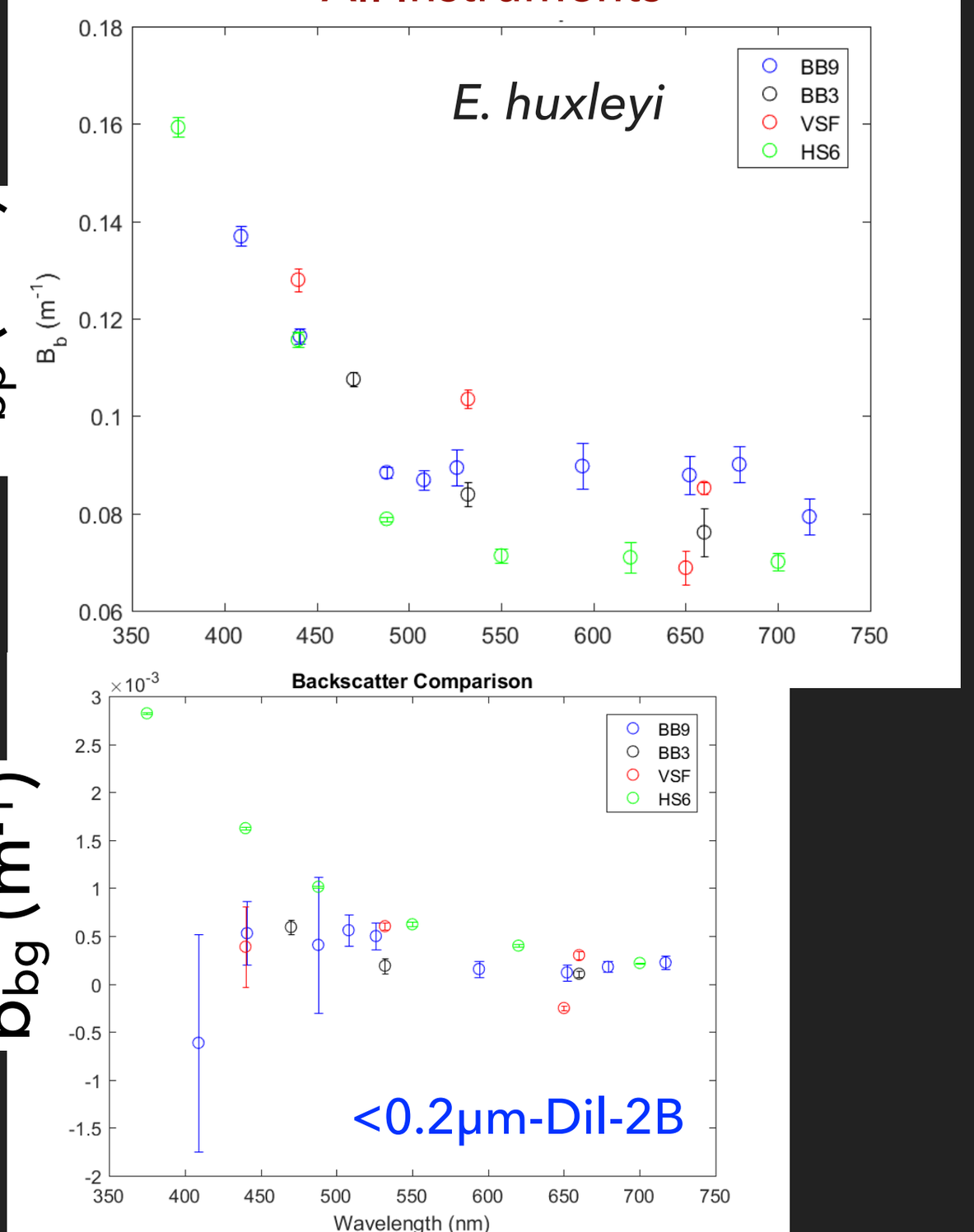


BACKSCATTER COMPARISONS

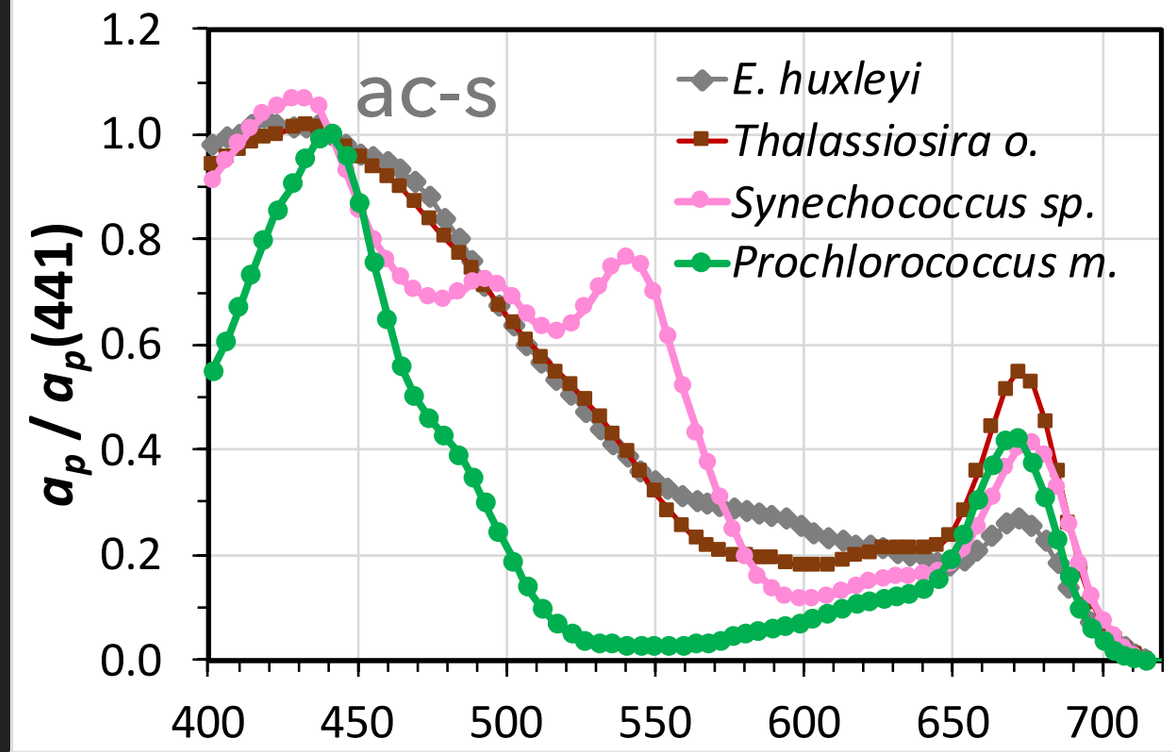
VSF-3 & HS-6

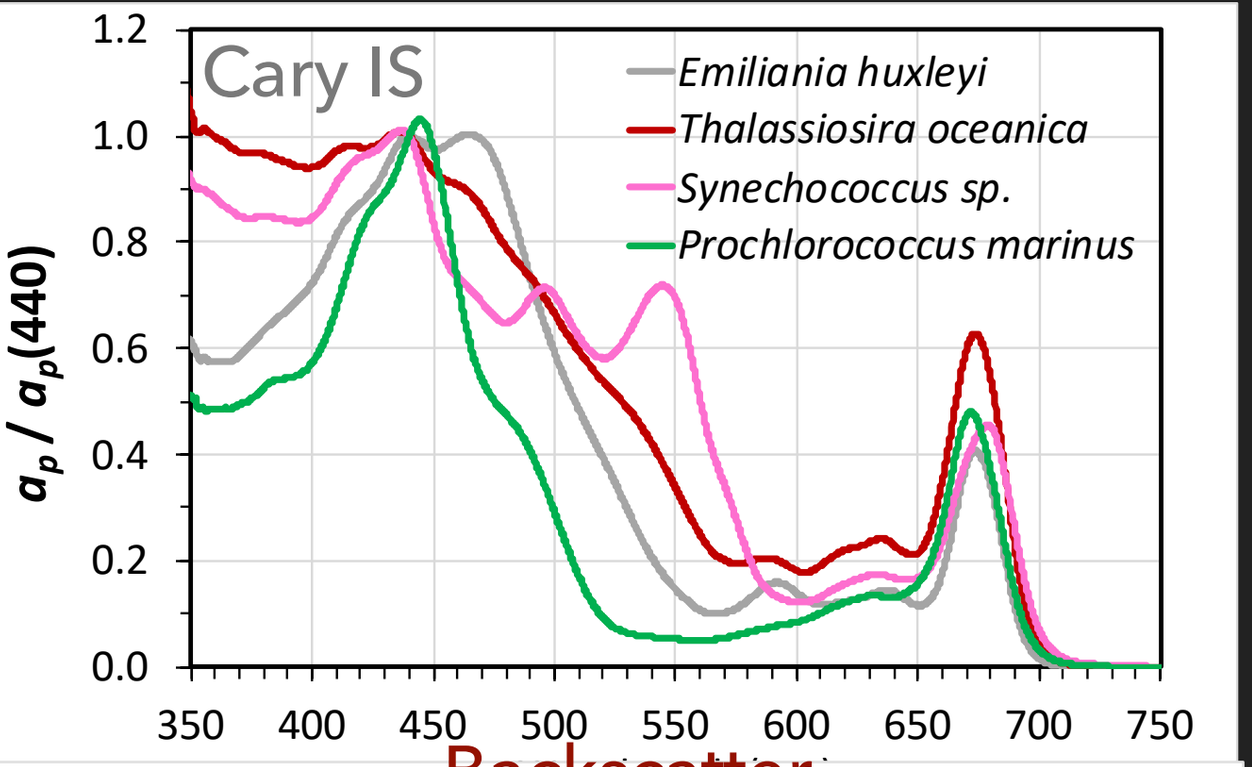


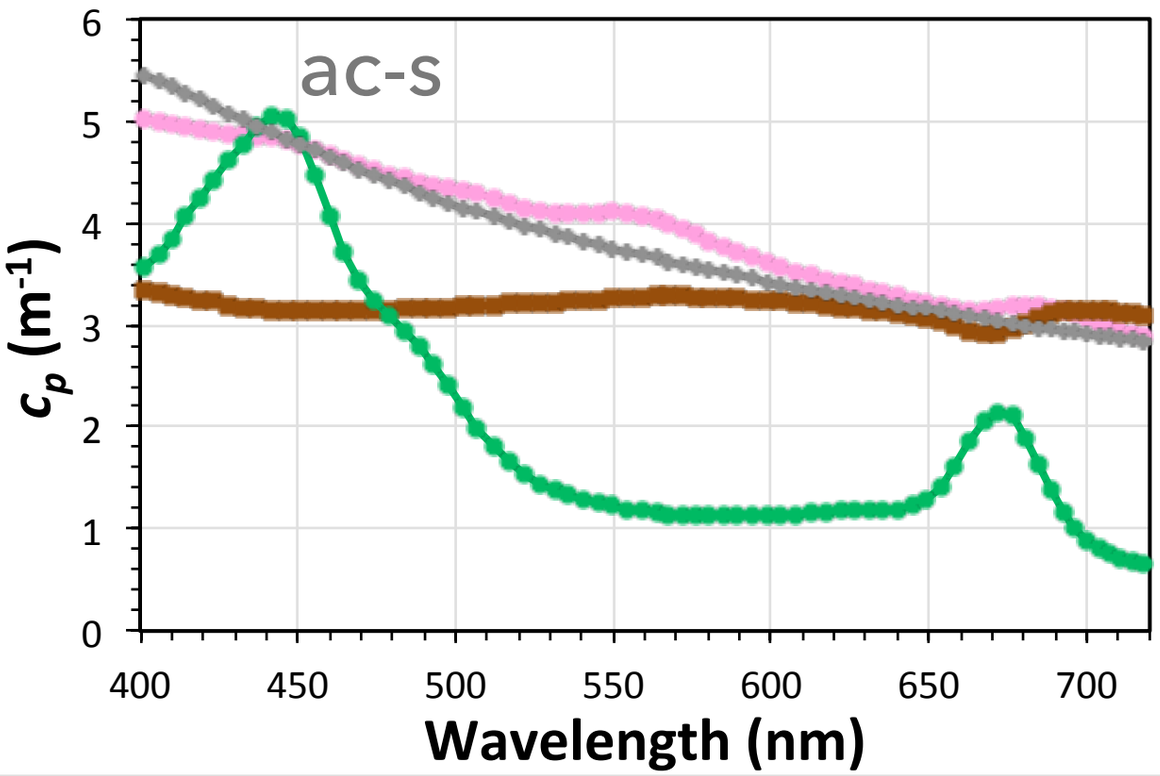
All Instruments

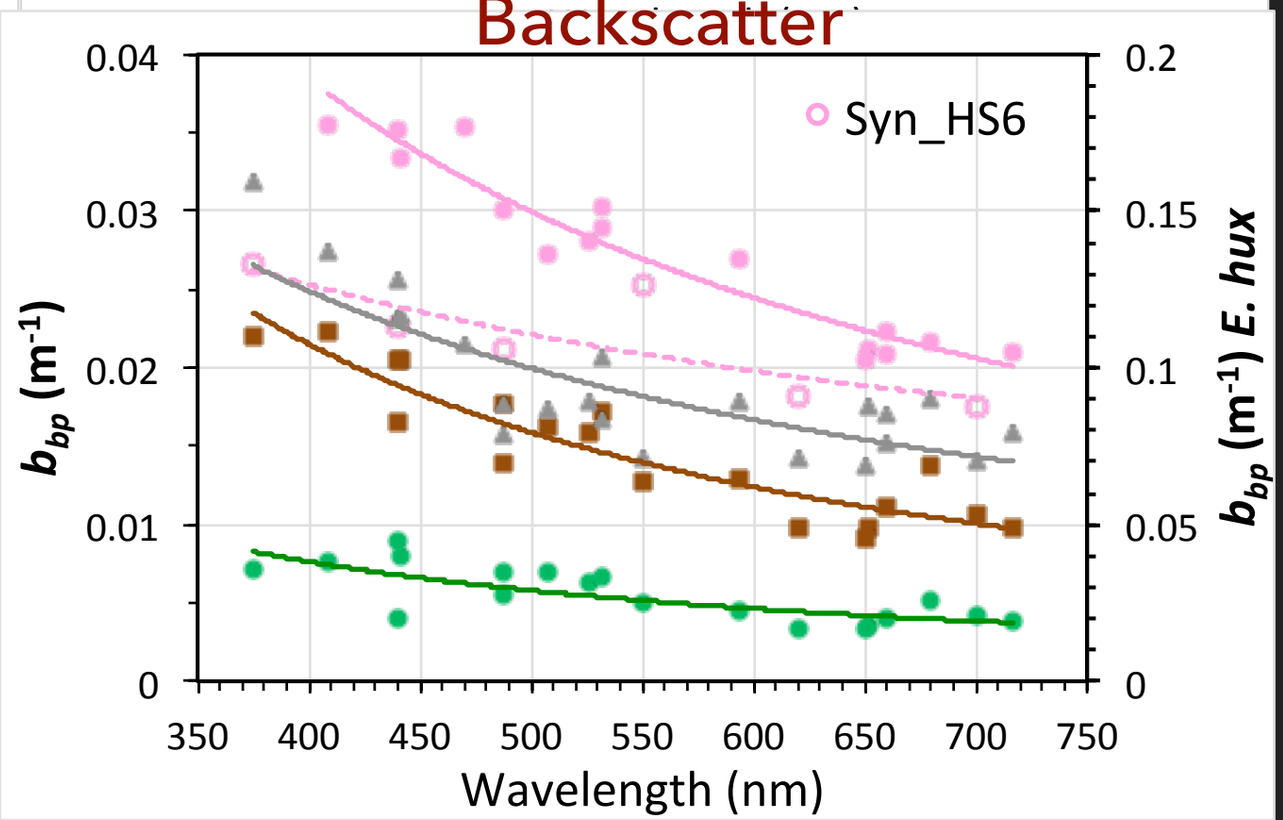


IOP RESULTS – GLOBALLY SIGNIFICANT PHYTOPLANKTON





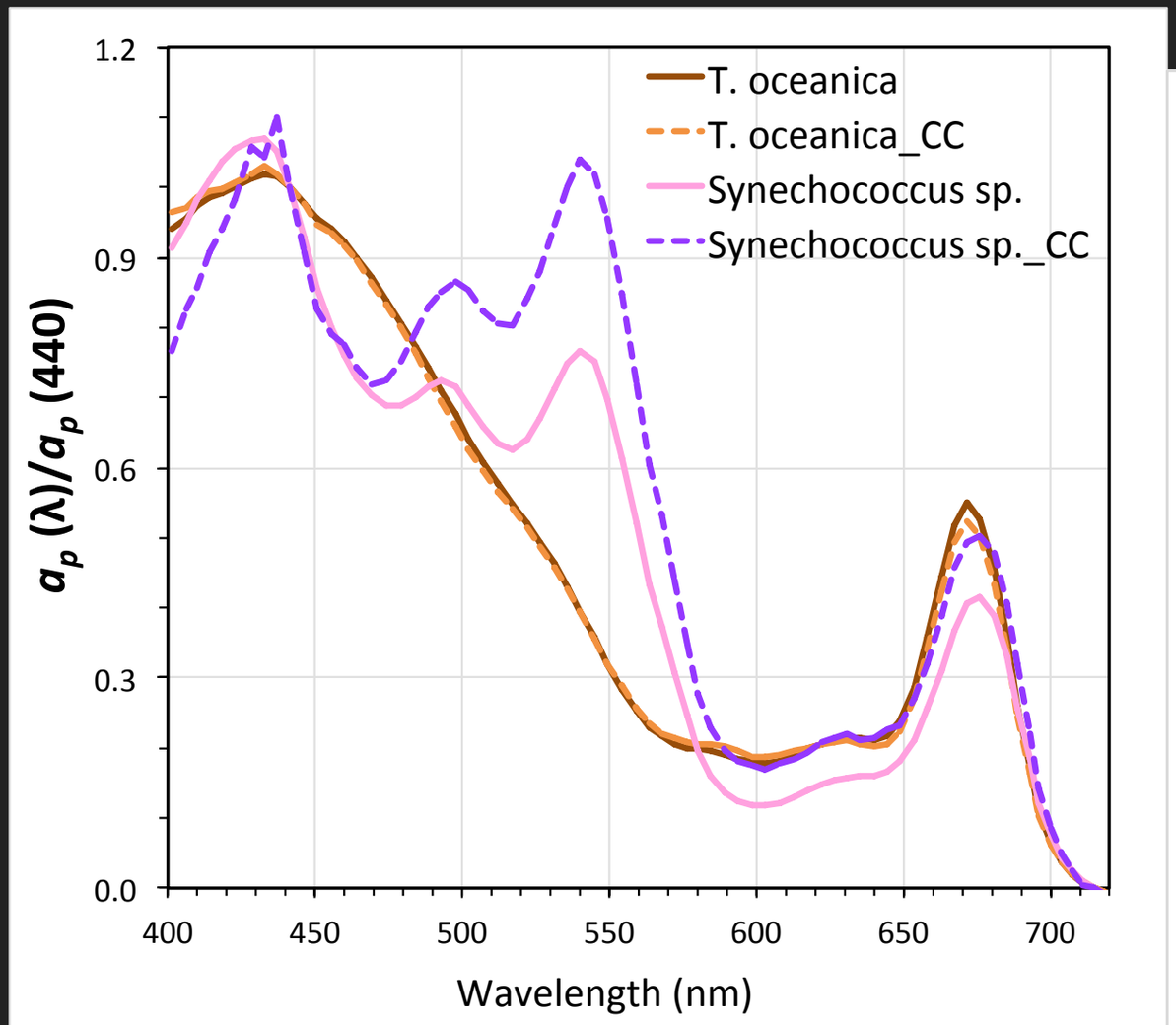




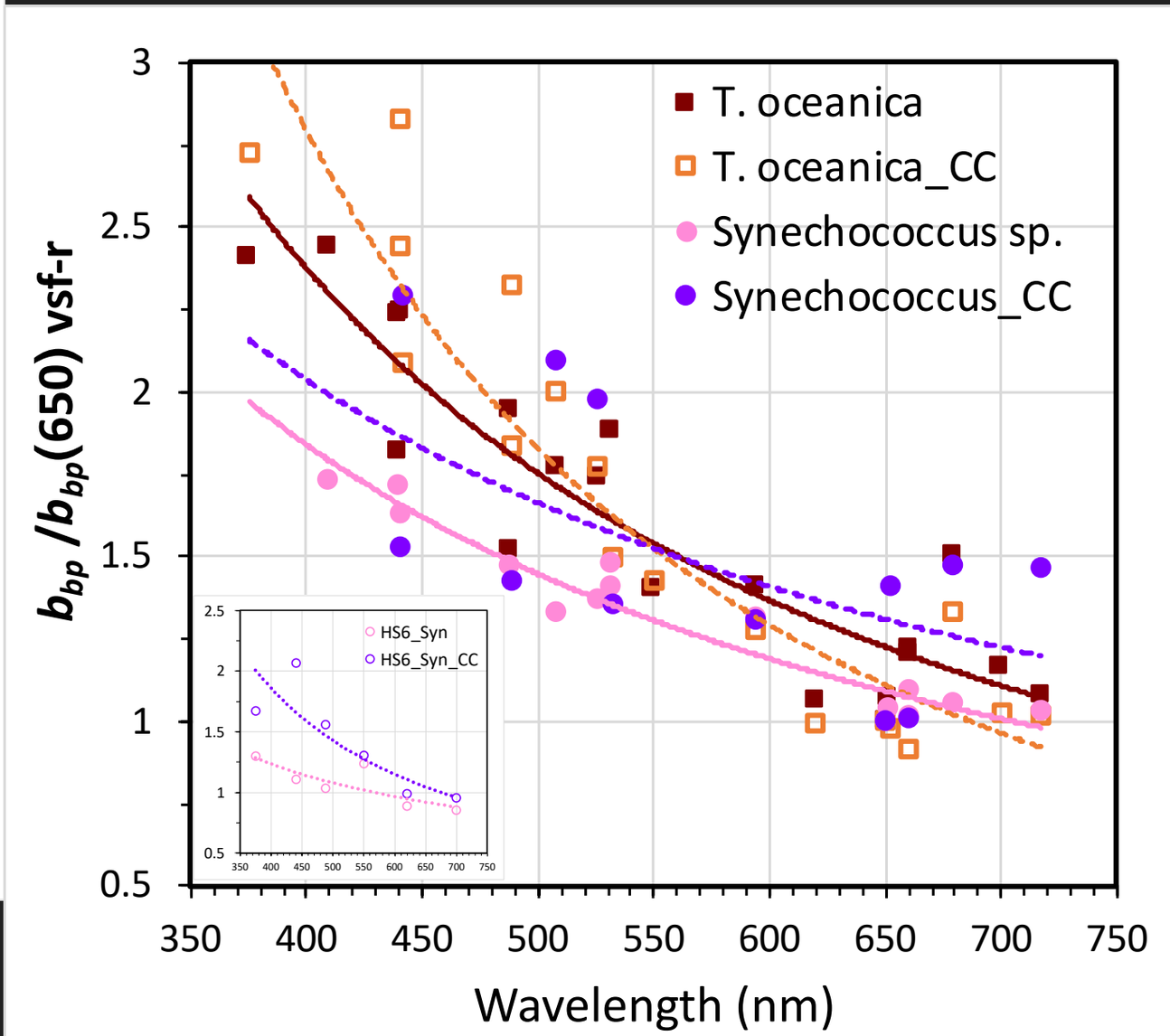
IOPs IN CLIMATE CHANGE EXPERIMENT (+TEMP, +LIGHT, +CO_2)

+4°C, +30% Light, +0.5% CO_2

Absorption: $a_p/a_p(440)$

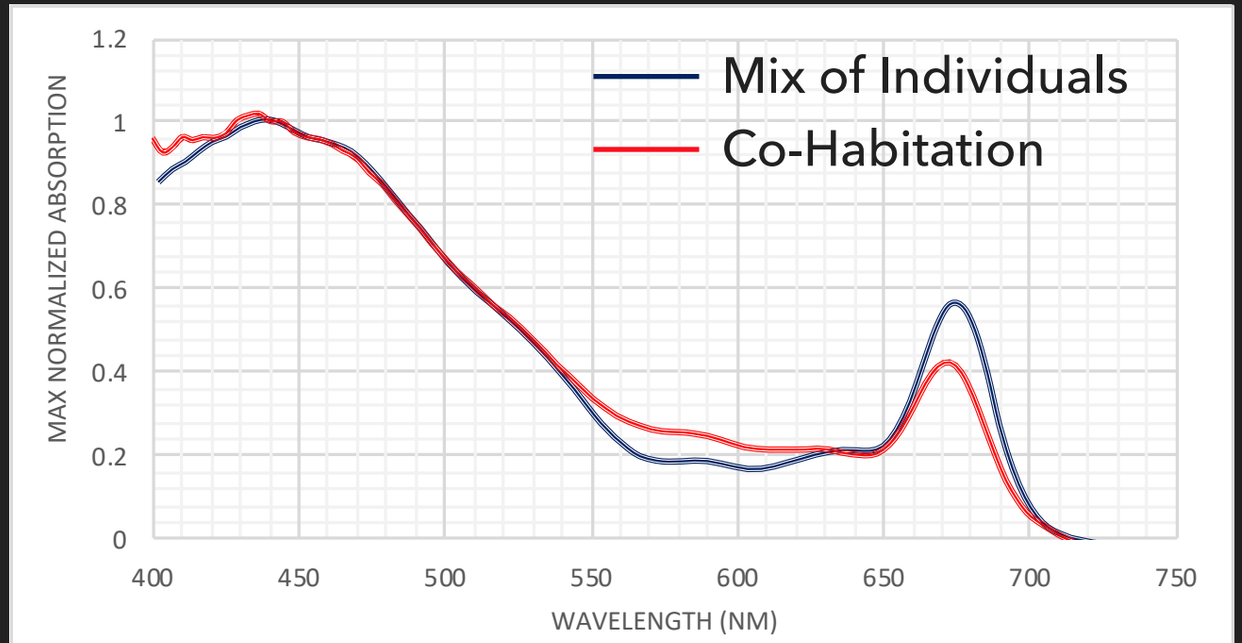


Backscatter: $b_{bp}/b_{bp}(650)$

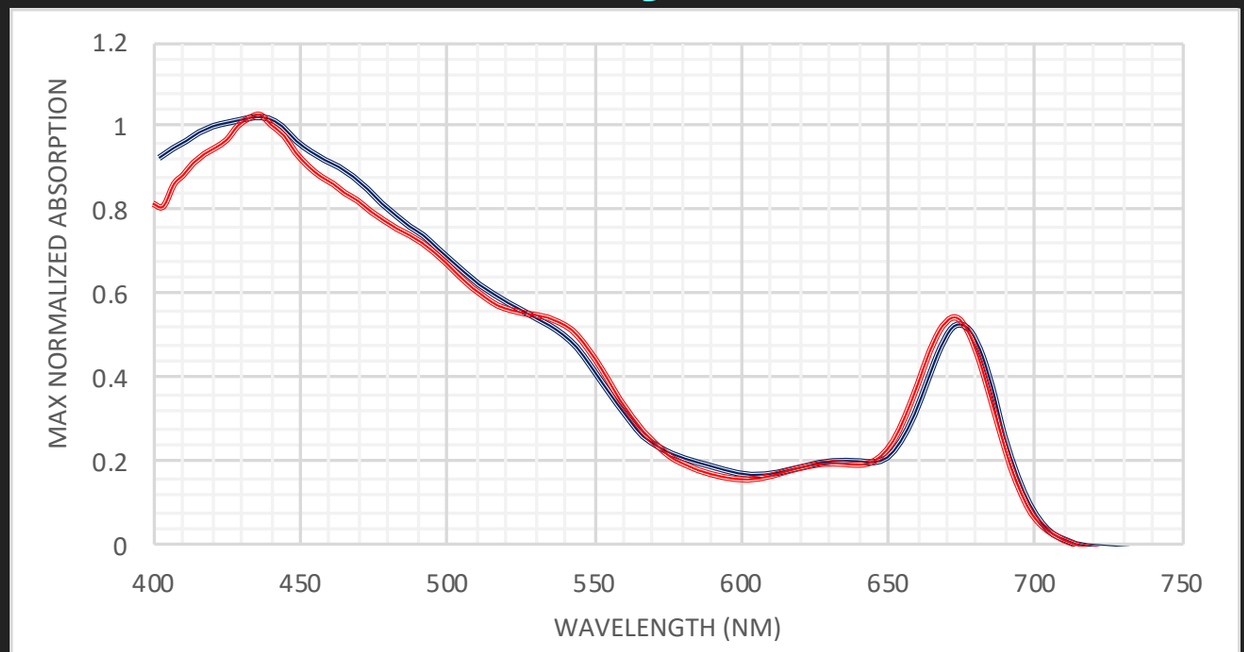


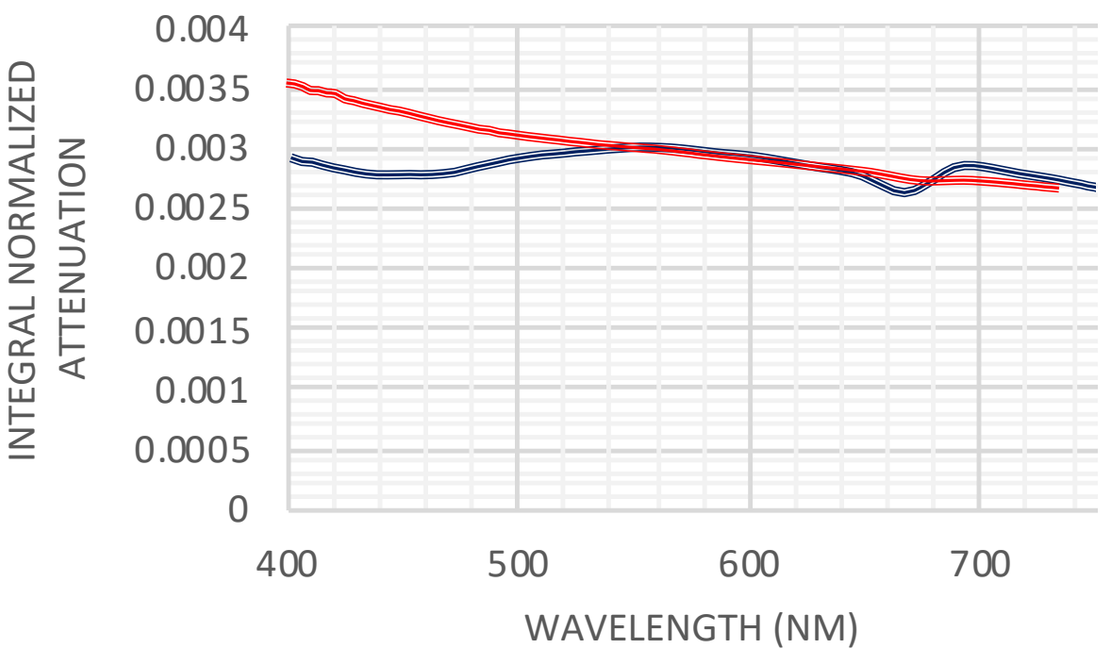
CO-HABITATION VS MIXTURES OF MONO-SPECIFIC CULTURES

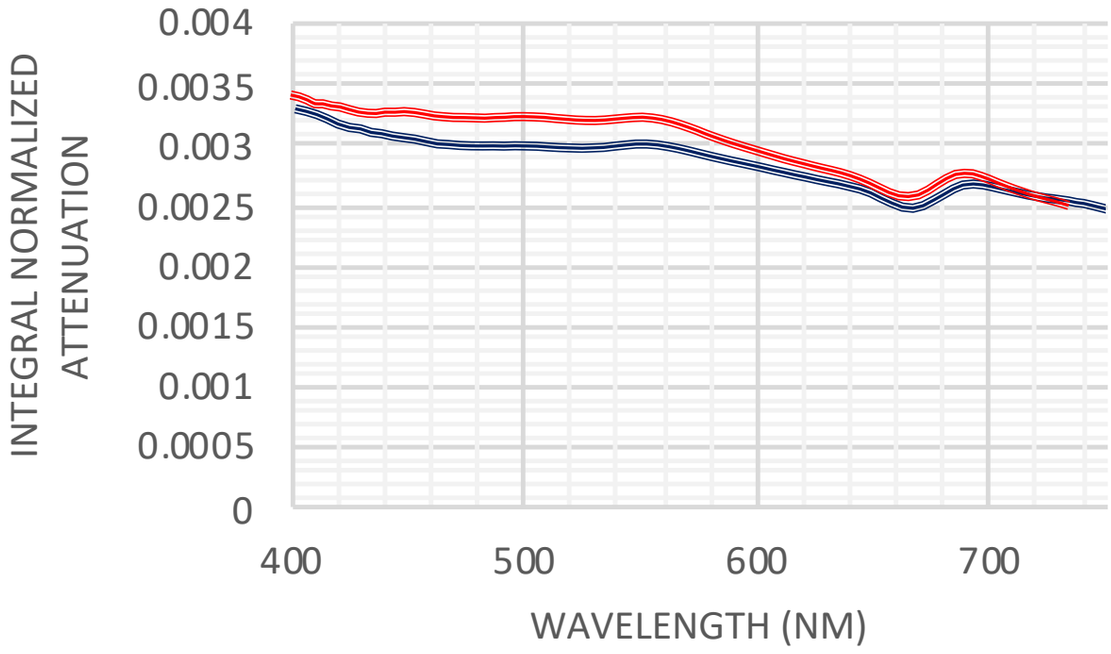
T. oceanica & E. hux



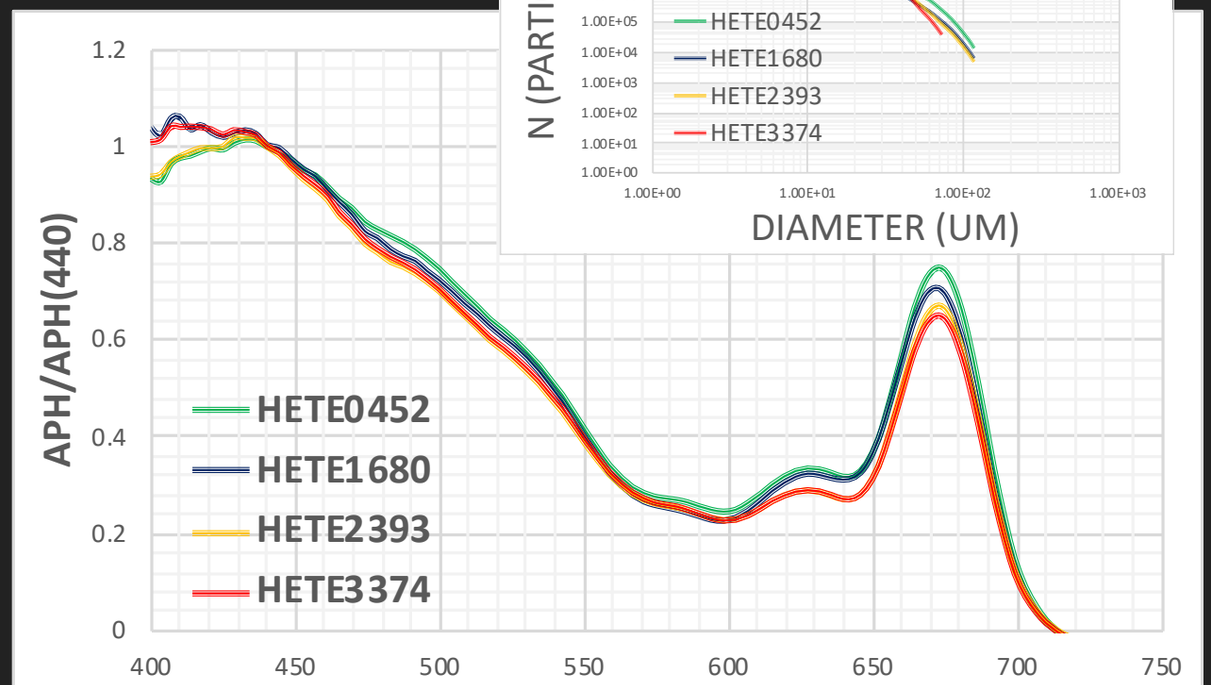
T. oceanica & Synechococcus



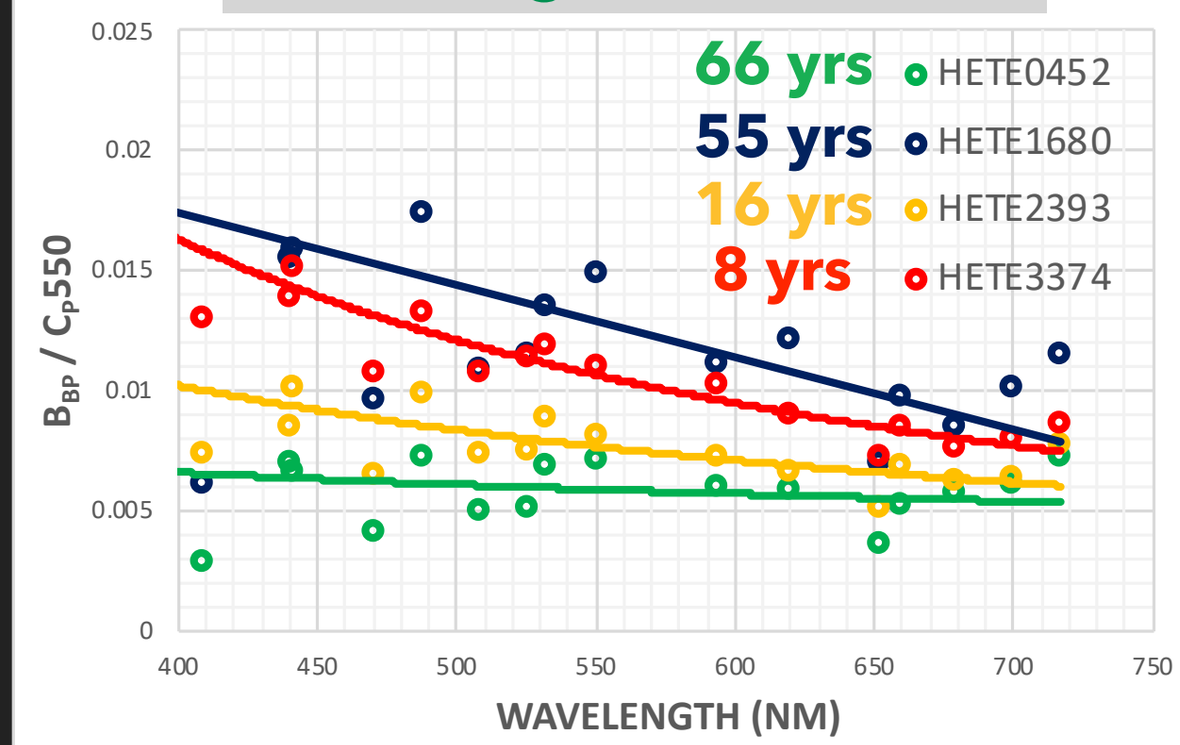




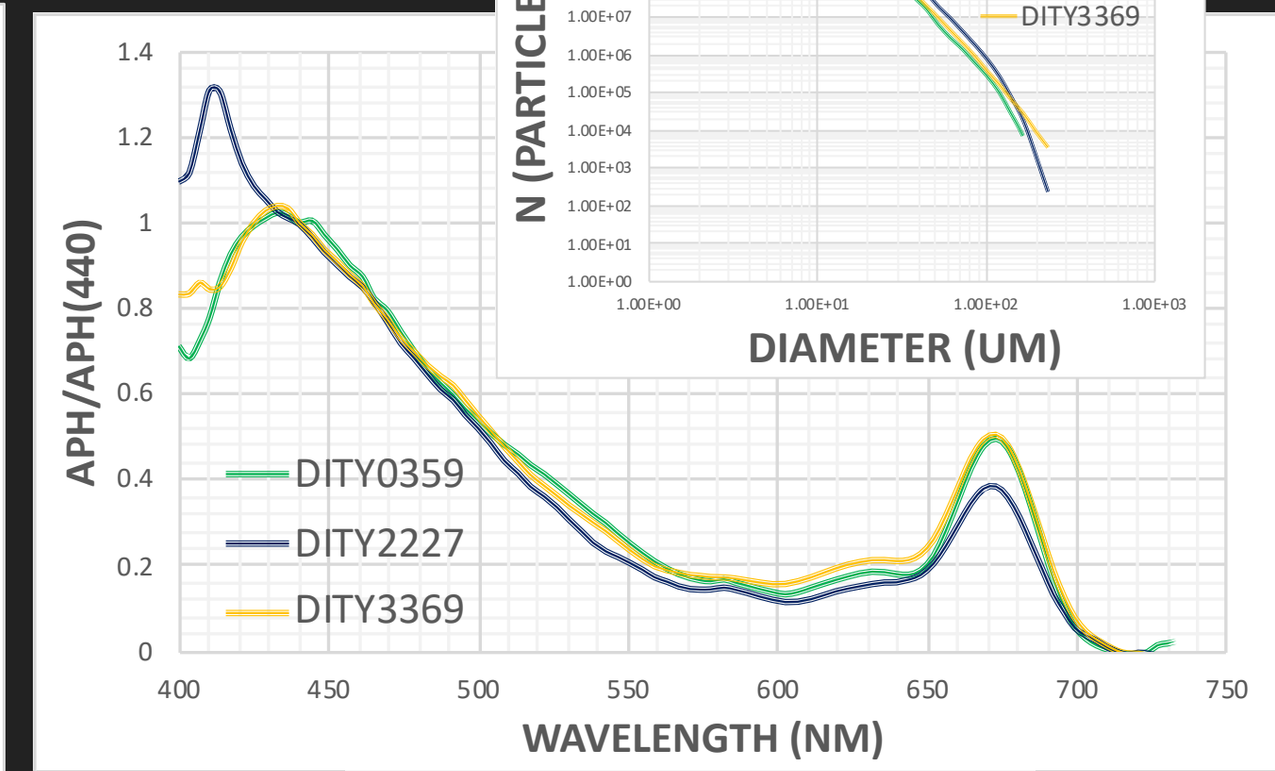
ADAPTATION



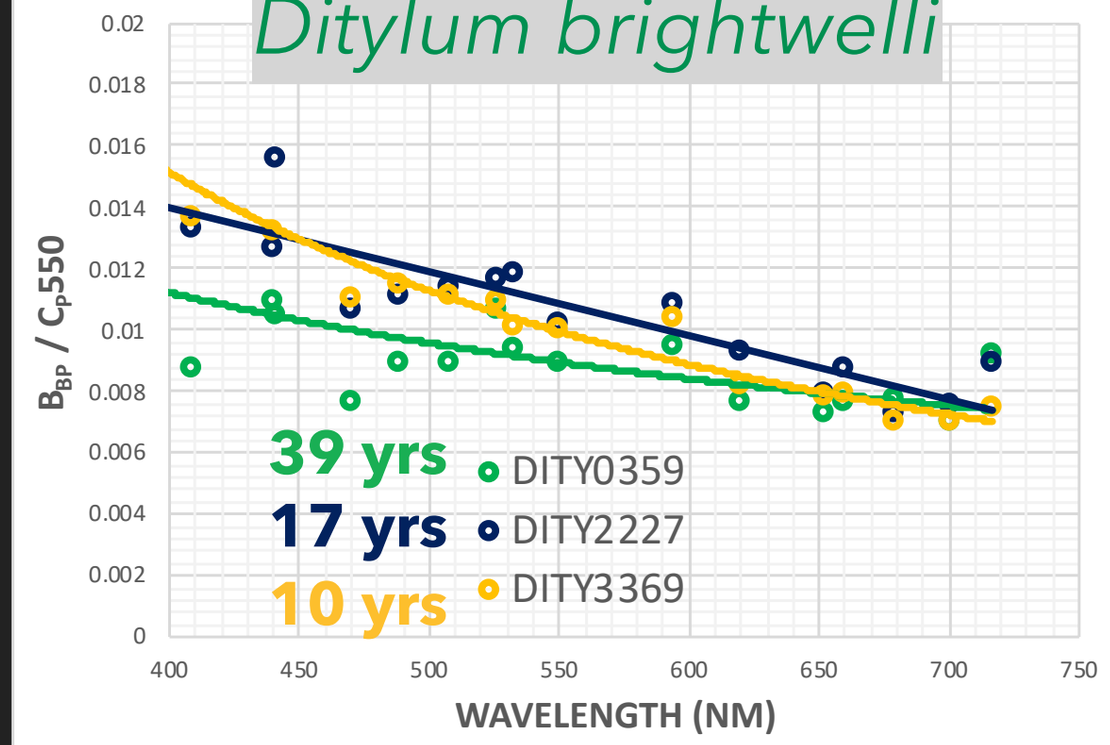
Heterosigma akashiwo



IN CAPTIVITY

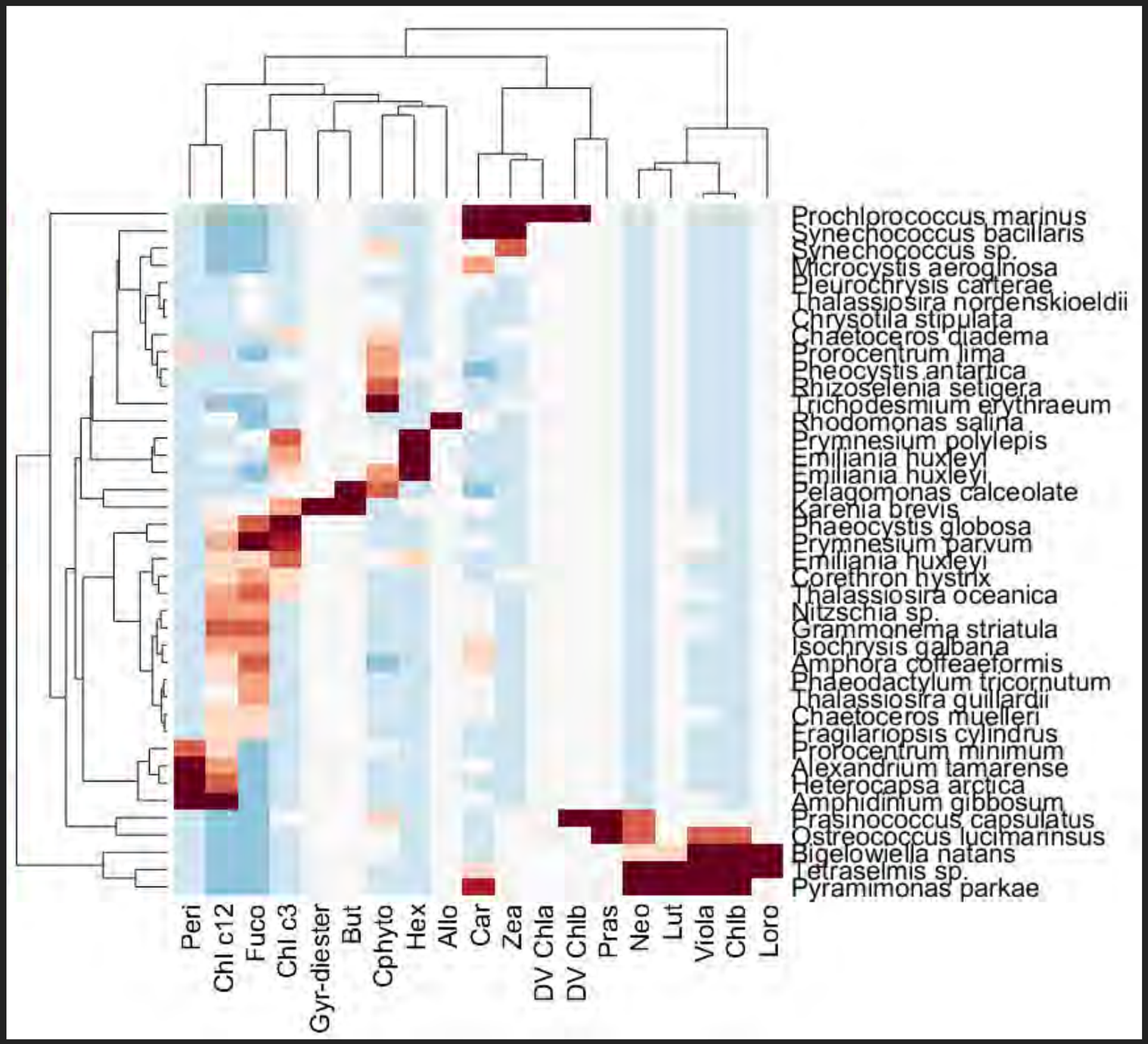


Ditylum brightwelli



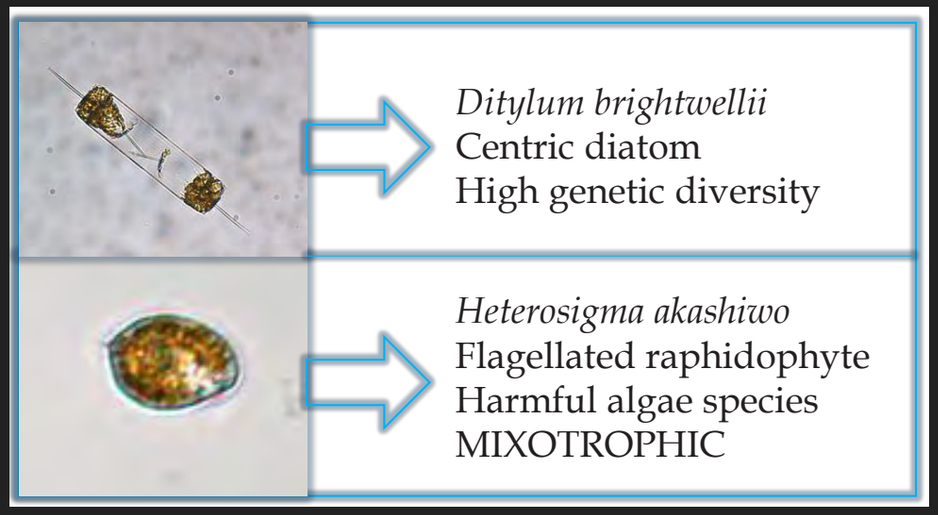
C_PHYTO CHEMTAX

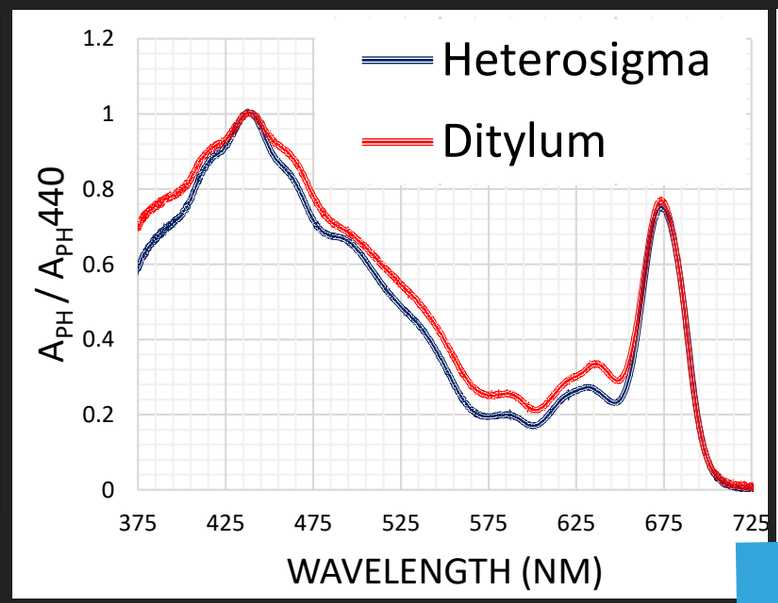
- CHEMTAX applied to estimate abundances of taxonomic groups using in situ pigments.
- CHEMTAX relies on accurate regional diagnostic pigment-to-Chl-a ratios for a region of interest.
- C_phyto is preferred indicator of biomass.
- Developing a set of refined pigment-to-Chl-a and pigment-to-C_phyto ratios for the global application of CHEMTAX.
- Ratios are currently being tested on culture mixtures created by varying proportions of cell concentrations.

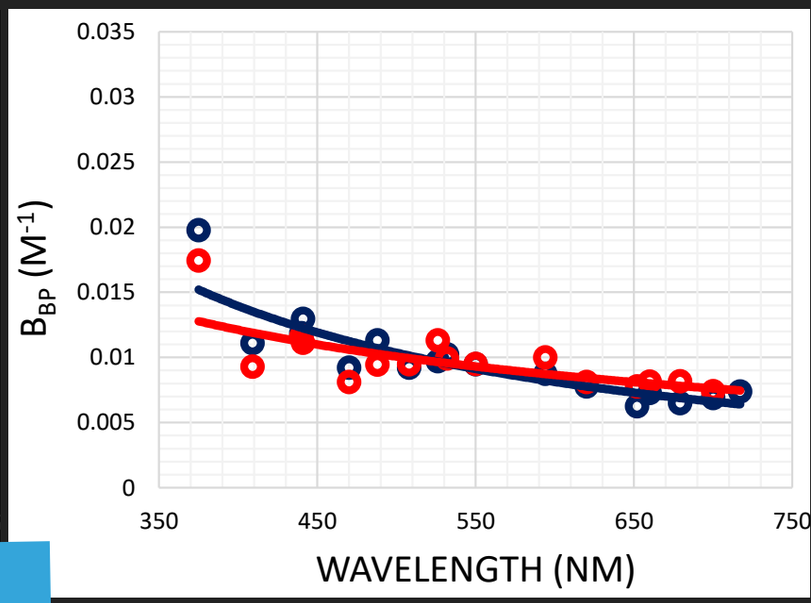


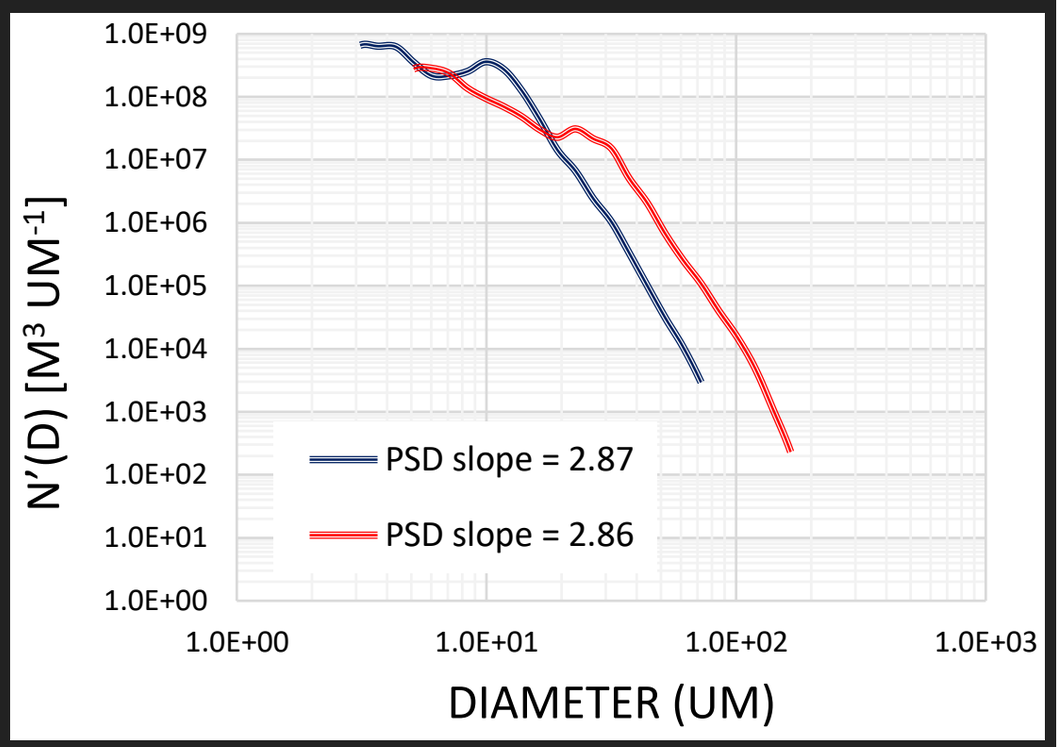
Ward cluster heat maps illustrating the distribution of pigment-to-C_Phyto ratios

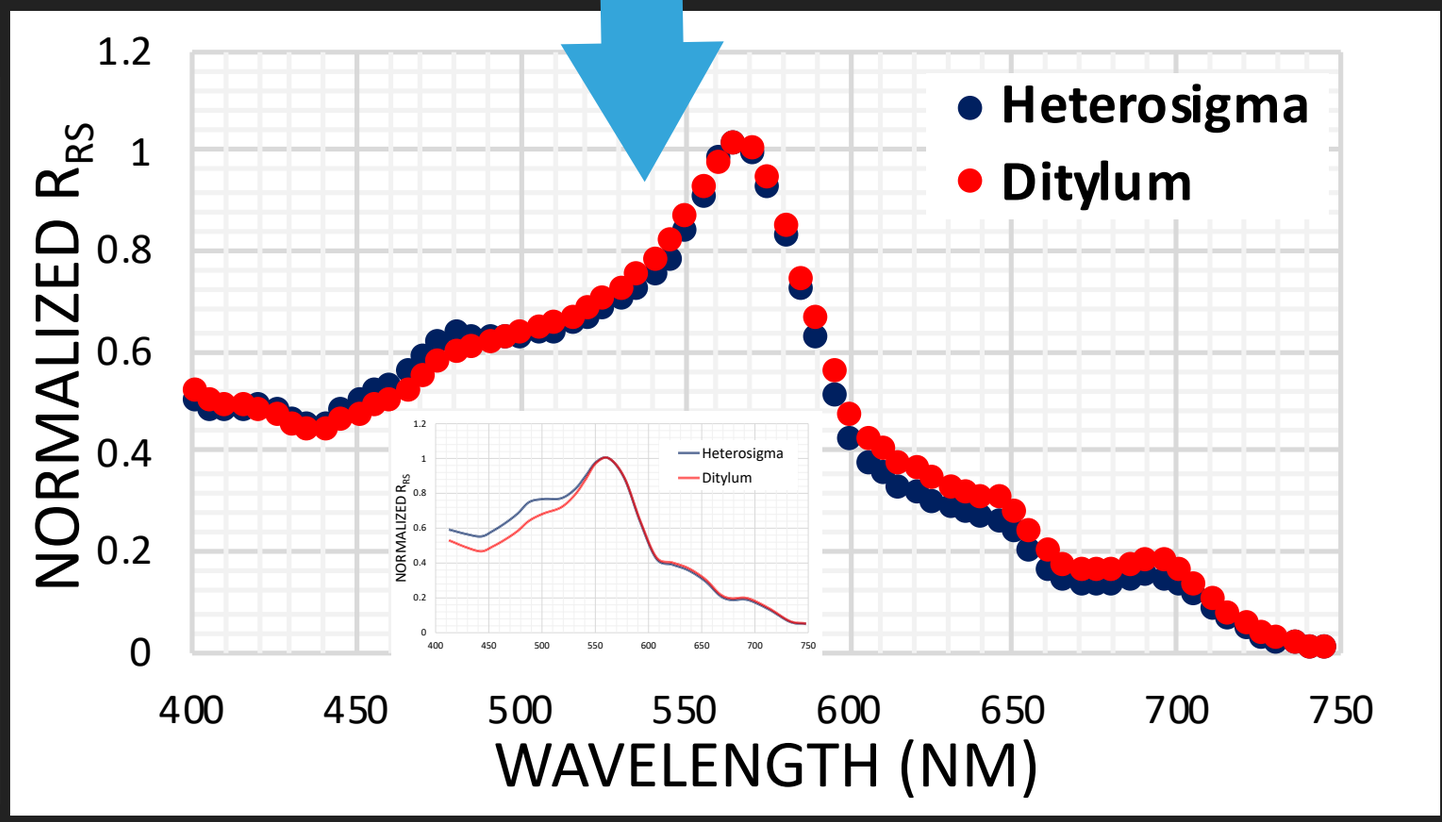
EXAMPLE OF 2 OPTICALLY SIMILAR SPECIES BUT DIFFERENT PFT











WHAT COMES NEXT?

- Experimental Data QA/QC, Analysis & Synthesis
- Build Spectral Library & CHEMTAX Library
- Algorithm development & evaluation
- Multi-decade in situ time-series data analysis
- Satellite data processing & analysis of study region time-series