Diel b_{bp} Cycles in Cultured Phytoplankton

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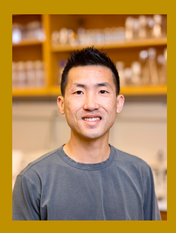
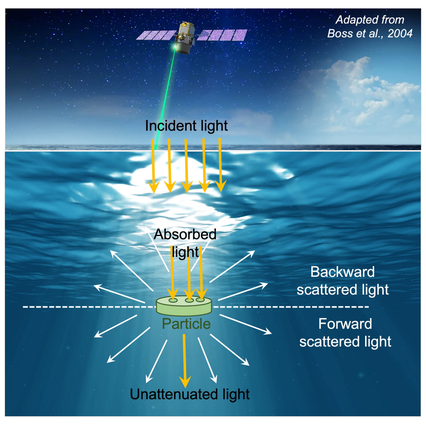


Background & Questions

Photons scattered by particles in the backwards direction (b_{bp}) have the potential to leave the ocean surface and be detected by remote sensing. b_{bp} is a proxy for particle abundance but is also dependent on particle refractive index. Global b_{bp} has been reported to vary over diel timescales and has been shown to increase in laboratory phytoplankton cultures from sunrise to sunset.



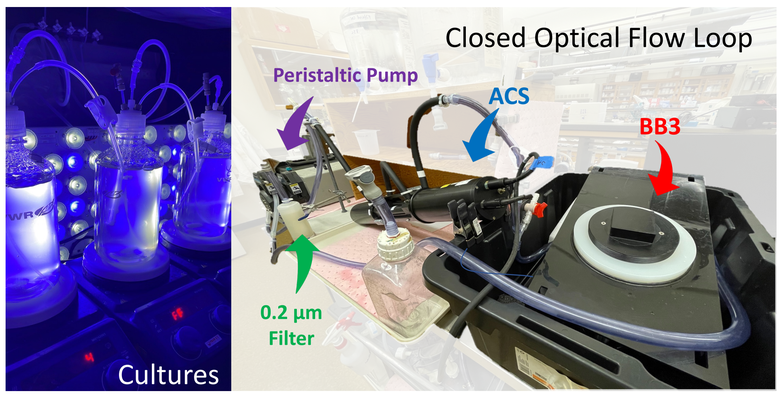
Q1: What is the contribution of phytoplankton to b_{bp} variability over a *complete* diel cycle?

Q2: How does this contribution vary across species?

Hypotheses & Approach

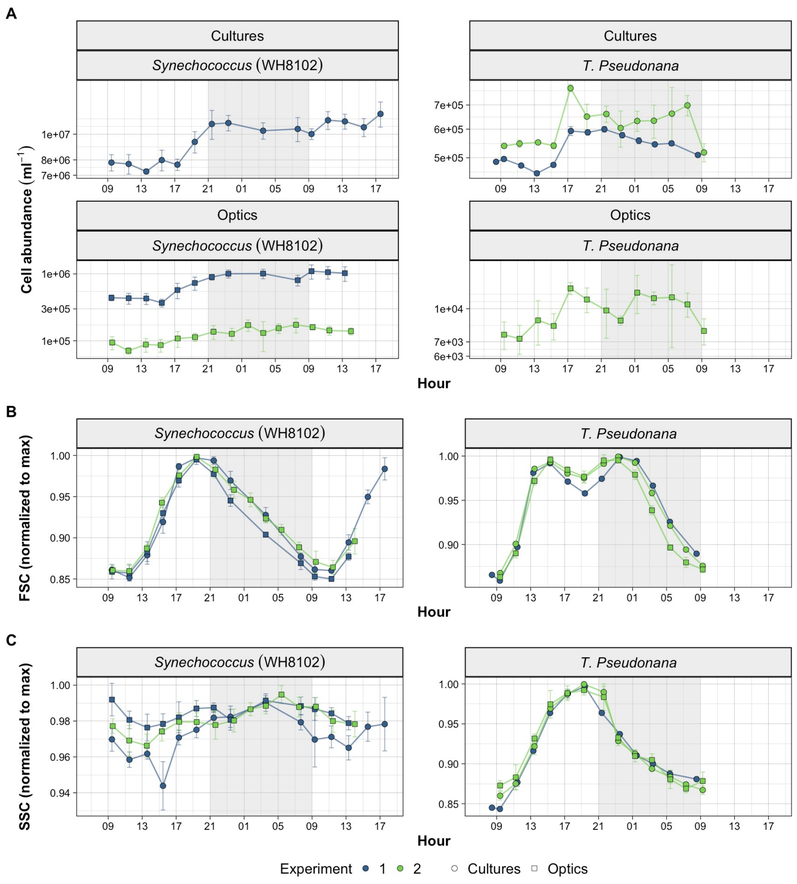
H1: Diel variations of b_{bp} will reflect increases in phytoplankton size and organic carbon content during the day and decreases during the night due to division and respiration.

H2: The magnitude and timing of diel changes in b_{bp} will be heavily influenced by the degree of cell cycle synchronization, which can be greater for some species relative to others.



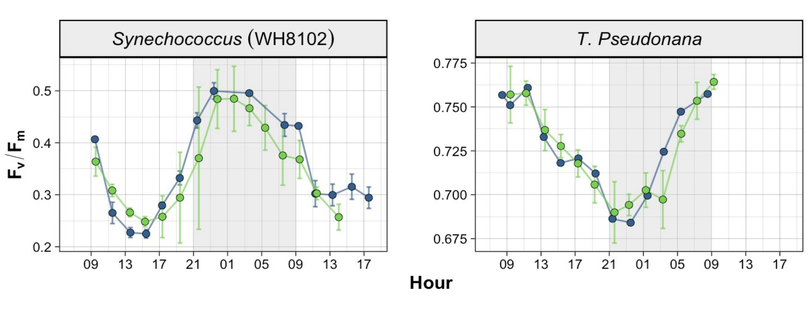
Phytoplankton	• *Thalassiosira pseudonana* (TP) • *Synechococcus* WH8102 (SYN)
Growth Conditions	• Nutrient-replete • 18˚C • 12:12 h sinusoidal light:dark period (dawn = 9:00, noon = 15:00, dusk = 21:00)
Optics Measurements (every 2 h for ≥ 24 h)	• WET Labs ACS: Particulate absorption (a_p) & attenuation (c_p) • ECO-BB3: Particulate backscattering (b_{bp}) & efficiency (b_{bp}/b_p)
Ancillary Measurements (every 2 h for ≥ 24 h)	• Flow cytometry • Fast-repetition rate fluorometry (FRRf) • POC/PON & cell composition • Scanning Electron Microscopy (SEM)

Synchronized Cell Division



- A: Both phytoplankton species displayed synchronized cell division, with SYN division (μ = 0.43 d^{-1}) occurring over a shorter time span than TP (μ = 1.1 d^{-1}). *Note: TP cultures were diluted to starting concentrations when μ > 0 (TP division between 1700 and 0900).*
- B: FSC (forward scatter: cell size proxy) increased during the day and decreased during night-time division and respiration.
- C: SSC (side scatter: changes with size, but more sensitive to cell complexity and granularity than FSC) showed similar diel cycle for TP but out of phase with division for SYN.

Photosynthetic Efficiency



Variable to maximum fluorescence (F_v/F_m) of changes in response to available light for both phytoplankton.

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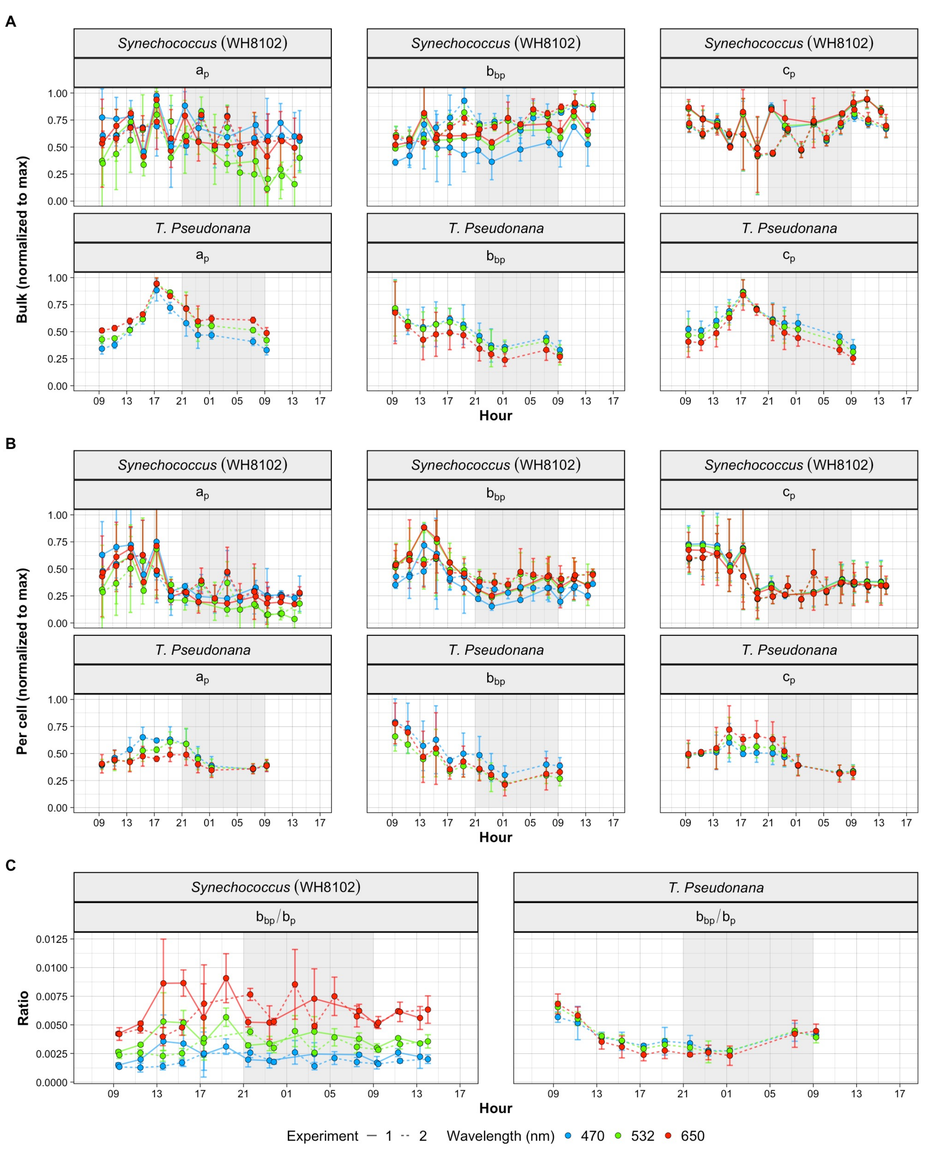
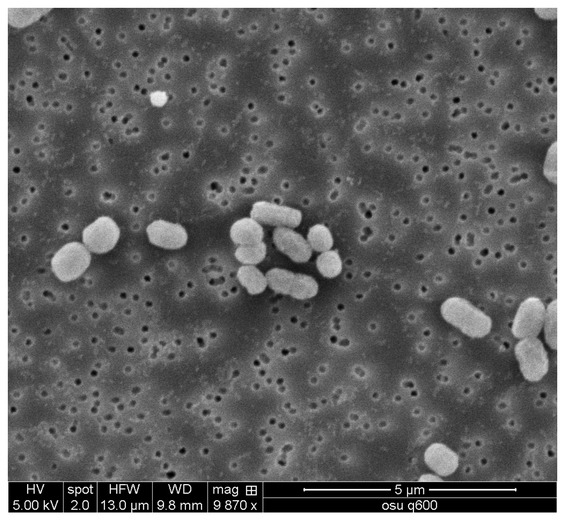
Diel Cycles in Optical Properties

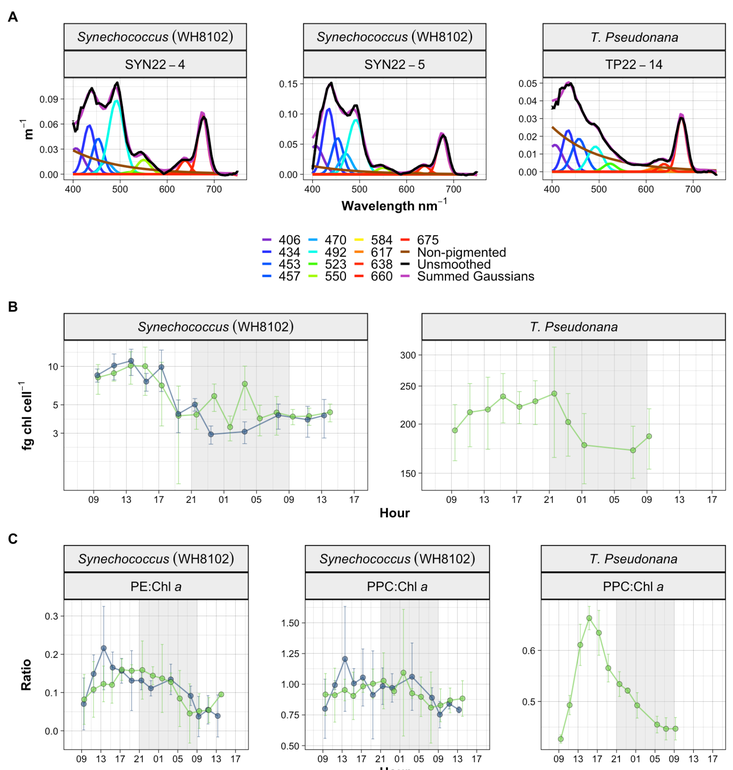


- Bulk optical properties showed diel variability for only TP (A), while normalized properties show similar patterns between species (B).
- Coefficients are maximal prior to cell division during the day and then decrease following division, reaching minima during the night.
- Changes in a_p and c_p are more pronounced for SYN while changes in b_{bp} are comparable between the two phytoplankton.
- b_{bp}/b_p varies over the diel cycle for TP but not for SYN (C).
- Little to no spectral dependence for any of the properties for either phytoplankton, except for b_{bp}/b_p for SYN.



SEM image of Synechococcus from 05:00.

a_p Spectral Decomposition & Pigment Ratios



- A: examples of Gaussian decomposition of absorption spectra
- B: cell-normalized chlorophyll concentrations estimated from absorption line height at 676 nm
  - ➢ Follows pattern of cell division, with a 5 h to 6 h lag for TP.
- C: ratios of Gaussians for phycoerythrin (PE, 550 nm), photoprotective carotenoids (PPC, 492 nm), and chlorophyll a (Chl a, 675 nm)
  - ➢ Diel patterns in pigment ratios follow changes in light intensity and are dampened for SYN relative to TP.

Conclusions

- Diel variations in b_{bp} generally reflect changes in the cell cycle and photophysiology. However, the timing of b_{bp} peaks and valleys can be out of phase with cell abundance, photosynthetic efficiency, and pigment ratios.
- The pronounced diel changes in phytoplankton b_{bp} suggests that time of day is an important consideration for interpreting satellite b_{bp} retrievals.