Seasonal shifts in division rate determine *Synechococcus* population dynamics

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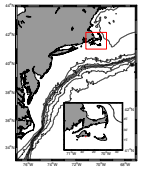
Introduction & Background

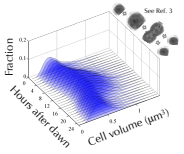
Synechococcus is a significant primary producer in coastal and open ocean systems. A key trait for understanding changes in its population abundance over time is the rate of cell division. For phytoplankton, the diel change in cell size distribution can be related to division rate. We use a matrix population model, fit to hourly cell size distributions, to estimate daily division rates of the *Synechococcus* population at the Martha's Vineyard Coastal Observatory for an 11-year time series. This method effectively links an individual trait (cell size) to a population level trait (cell division). This approach opens a path to quantify the role of *Synechococcus* in ecological and biogeochemical processes in natural systems.

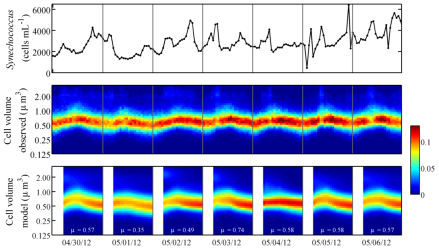
Study Site: Martha's Vineyard Coastal Observatory (MVCO), operated by the Woods Hole Oceanographic Institution, is a cabled research facility that provides real time and archived oceanographic and meteorological data.



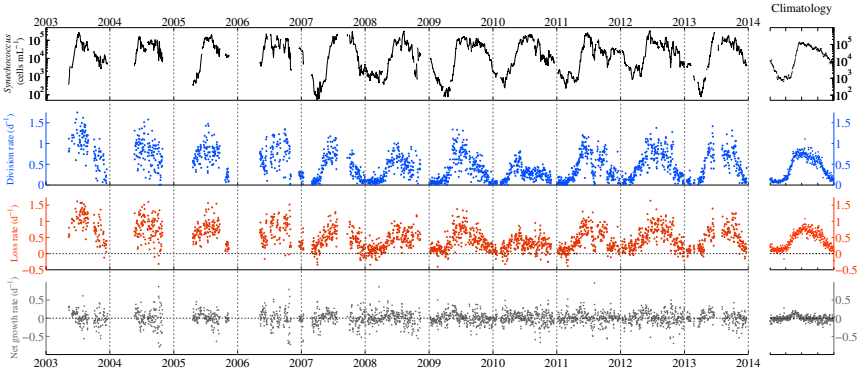
FlowCytobot: At MVCO, a custom built submersible flow cytometer, "FlowCytobot"[1] enables continuous measurement of picophytoplankton for extended periods of time.

Matrix Population Model: To estimate division rates, we use a matrix population model that represents diel changes in cell size. This approach is able to accurately estimate division rates of *Synechococcus*[2], and estimates are independent of abundance. The model is fit to time series of cell size distributions obtained from FlowCytobot and the fitted model provides an estimate of the in situ, daily population division rate.





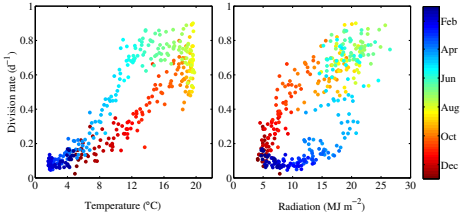
Seasonality of *Synechococcus* abundance, division and loss rate

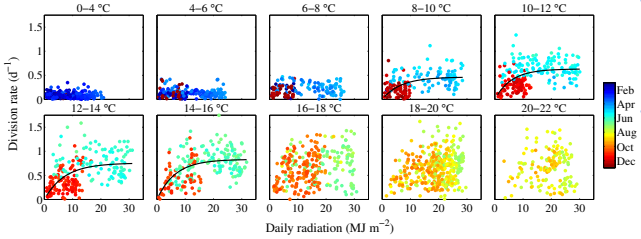


- Cell abundance, division rate and loss rate demonstrate striking seasonality. Net growth rate (calculated from daily change in abundance) hovers near zero for most of the year. Loss rates are calculated as division rate minus net growth rate (from net change in abundance).

Seasonal temperature and light limitation

- Climatological relationships between division rate, temperature and radiation illustrate division rate limitation by temperature during winter and spring, and by light during the fall.
- No relationship is observed during the summer months, suggesting that other factors (e.g., nutrient availability) may limit division rate during this time.

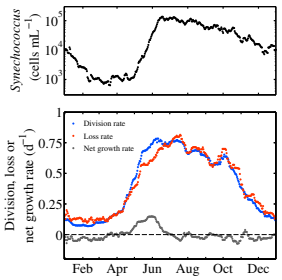


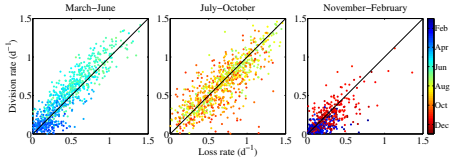


- For certain temperature windows, division rate demonstrates a saturating response to increasing radiation.
- In fall, division rates are along the light-limited portion of these curves (i.e., increasing with light level), while in spring, they are along the saturated portion (no increase with light level).

Loss rate is tightly coupled to division rate

- Loss rate closely tracks division rate in magnitude over the entire annual cycle
- This suggests that losses are mainly biological in nature (heterotrophic grazers, viruses), rather than from advection or mixing.





- The largest imbalance between growth and loss occurs during the spring bloom. The bloom is triggered by increasing water temperature, but accumulation of cells is determined by loss rate.
- Small, but systematic, offsets from zero net growth rate produce the large seasonal changes in cell abundance.

Conclusions

- Seasonal pattern of division rate is due to temperature limitation in winter and spring and light limitation in the fall.
- While seasonality of division rate determines growth, loss processes are equally important for shaping abundance patterns. A fine balance between growth and loss processes determine the dramatic seasonal changes in *Synechococcus* cell abundance.
- Long term observations at the appropriate temporal resolution are critical for understanding plankton dynamics and how key traits, such as division rate, vary over the seasonal cycle.
- Next steps: Understand how division rate varies among *Synechococcus* isolates from MVCO. Physiological characterization of these strains will also provide comparisons for field data.

REFERENCES

[1]Olson, R. J., A. A. Shalapyonok, and H. M. Sosik. 2003. An automated submersible flow cytometer for pico- and nanophytoplankton: FlowCytobot. Deep-Sea Res. I **50:** 301-315.

[2]Hunter-Cevera, K.R., Neubert M.G., Solow, A.R., Olson, R.J., Shalapyonok,A. and H.M. Sosik. (2014). Diel size distributions reveal seasonal growth dynamics of a coastal phytoplankter. PNAS. **111**(27): 9852-9857.

[3]Waterbury, J.B. Watson, S.W., Valois, F.W., and D. G Franks. Biological and ecological characterization of the marine unicellular cyanobacterium *Synechococcus*. Canadian Bulletin of Fisheries and Aquatic Sciences, 214:71–120, 1986.