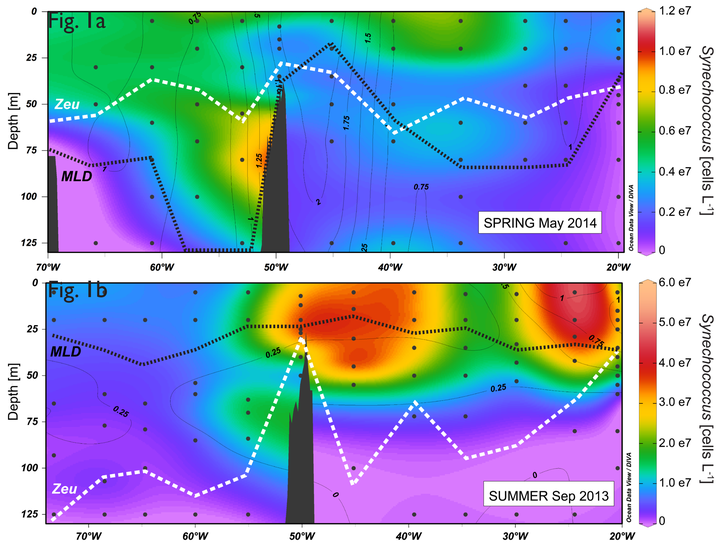
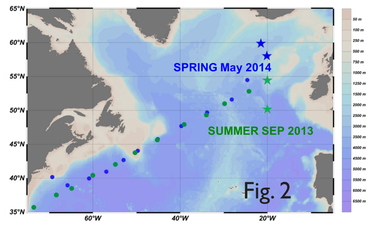
Phytoplankton production from community to cell-specific rates

N. Van Oostende[1], S. E. Fawcett[1,2], J.T. Carroll[1] and B. B. Ward[1]
[1] Department of Geosciences, Princeton University; [2] University of Cape Town, South Africa

Bess Ward, bbw@Princeton.EDU
N. Van Oostende, oostende@Princeton.EDU

Synechococcus abundance seasonal and geographical variation





Late summer *Synechococcus* cell abundance was at least five times higher during late summer than in spring along North Atlantic Ocean transects (Figs. 1 & 2) (Van Oostende et al. 2016).

Nutrient rich springtime was characterized by low temperature and light levels, while in summer high light and temparature and low nutrient concentrations were prevalent.

Whole community and microphytoplankton carbon and nitrate specific uptake rates

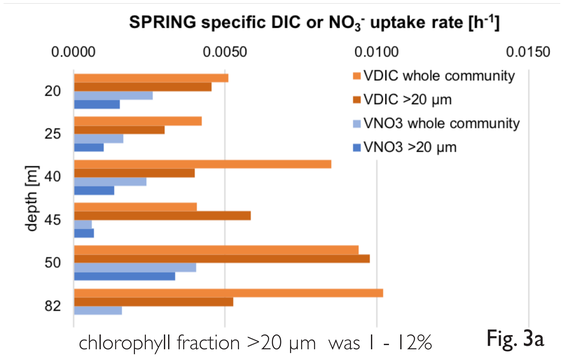


Fig. 3a

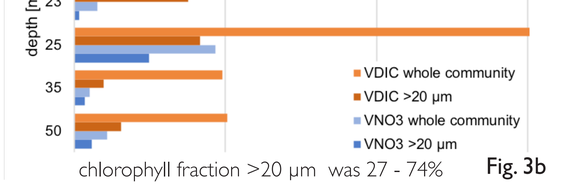


Fig. 3b

Whole community carbon specific uptake rates (VDIC) were higher in summer compared to spring (Fig. 3) at four temperate and subarctic process stations (stars in Fig. 2). Nitrate specific uptake rates (VNO3) had a similar range, pointing to the uptake of other nitrogen sources, such as ammonium and other reduced forms, to sustain production in the summer (Fig. 3) (Peng et al. 2018).

Microphytoplankton VDIC were always at least two times lower than whole community rates in summer (Fig. 3b), which is consistent with larger cells being less competitive at the low nutrient levels prevalent during summertime. By inference, smaller, pico- and nanophytoplankton cells were mostly driving production regardless of season.

Synechococcus and eukaryotes nitrate specific uptake rates

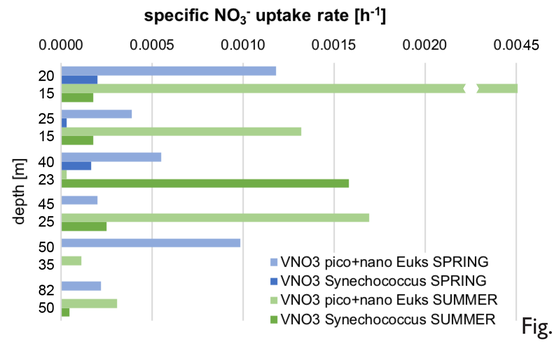


Fig. 4

Specific nitrate uptake rates by *Synechococcus* cells, measured on flow cytometry-sorted populations (cf. Fawcett et al. 2011), were always lower than sorted eukaryote phytoplankton's uptake rates in spring but not consistently so in summer at temperate and suarctic process stations (stars in Fig. 2). This highlights the different roles these two phytoplankton groups mostly have in terms of new production (i.e., nitrate fueled production), but also shows *Synechococcus* new production rate can sometimes outpace that of pico- and nanophytoplankton (Fig. 4).

Synechococcus replication rates measured by iRep

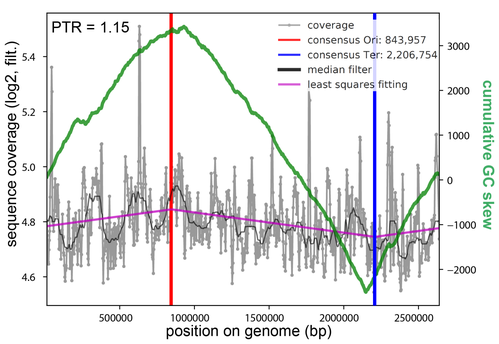


Fig. 5a

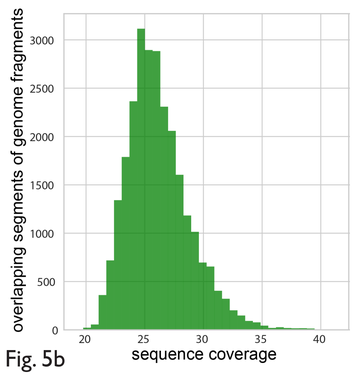


Fig. 5b

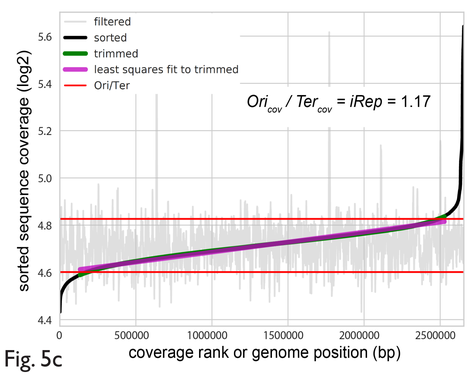


Fig. 5c

Replication rate estimates of *Synechococcus* WH8020 were obtained for the first time by applying the index of replication (iRep), a taxon-specific genome-based method (Brown et al. 2016), to experiments with non-axenic cultures. This approach will be applied to field samples to estimate *in situ* replication rates.

Differences in the number of copies of genome fragments across a population of replicating cells can be determined based on sequencing read coverage over complete genome assemblies (Fig. 5a). The peak to trough ratio (PTR) between coverage at the origin (peak) and terminus (trough) of replication relates to the replication rate of the population. The genome position of origin and terminus can be determined based on cumulative GC skew. The replication rate based on the distribution of coverage values across a draft-quality genome can be calculated using the iRep method. Coverage is first calculated across overlapping segments of genome fragments, which are then rank ordered. iRep is calculated as the ratio of the coverage values associated with the origin and terminus of replication.

Acknowledgements: This research would not have been possible without the support of the National Science Foundation grant n° OCE-1136345, PI's Ward and Sigman, and grant n° OCE-1747511, PI's Ward and Van Oostende. We are grateful to Martin Wolf for his help with elemental analyses, Qixing Ji for his help with isotopic measurements of sorted cells, and the captain and crew of the RV Endeavor for their professionalism.

Literature references: **Van Oostende et al. 2016**, Variation of summer phytoplankton community composition and its relationship to nitrate and regenerated nitrogen assimilation across the North Atlantic Ocean. Deep Sea Res. I. doi: 10.1016/j.dsr.2016.12.012; **Peng et al. 2018**, Nitrogen uptake and nitrification in the subarctic North Atlantic Ocean. Limnol. Oceanogr.. doi:10.1002/lno.10784; **Fawcett et al. 2011**, Assimilation of upwelled nitrate by small eukaryotes in the Sargasso Sea. Nature Geoscience. doi: 10.1038/ngeo1265; **Brown et al. 2016**, Measurement of bacterial replication rates in microbial communities. Nature Biotech. doi: 10.1038/nbt.3704