Noisy Sunlight: Algal Acclimation to Stochastic Light

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Natural sunlight exhibits not only dramatic shifts in intensity but also a background of rapid, irregular perturbations. While the physiological response to large, periodic fluctuations has been identified as a target for improving photosynthetic efficiency, the consequences of unpredictable fine-scale variation remain poorly understood. To address this gap, we created growth environments with stochastic light inputs such as unpredictable changes in frequency, mean, and variance. We were then able to assess the impact on photosynthetic performance through chlorophyll fluorescence and growth studies.

Wild-type *Chlamydomonas reinhardtii* and mutants deficient in various non-photochemical quenching mechanisms were grown under three regimes: (1) constant low light at 50 µmol m^{-2} s^{-1}, (2) a 12/12 diurnal sinusoidal cycle, and (3) the same diurnal cycle with added stochastic perturbations every 5 seconds, drawn from a normal distribution with mean 0 and standard deviation 10 µmol m^{-2} s^{-1}. Organisms exposed to stochastic perturbations showed lower Fv/Fm and increased NPQ induction. These results suggest that irregular, high-frequency light variation can drive acclimation not only to dynamic environments but also to unpredictable ones.

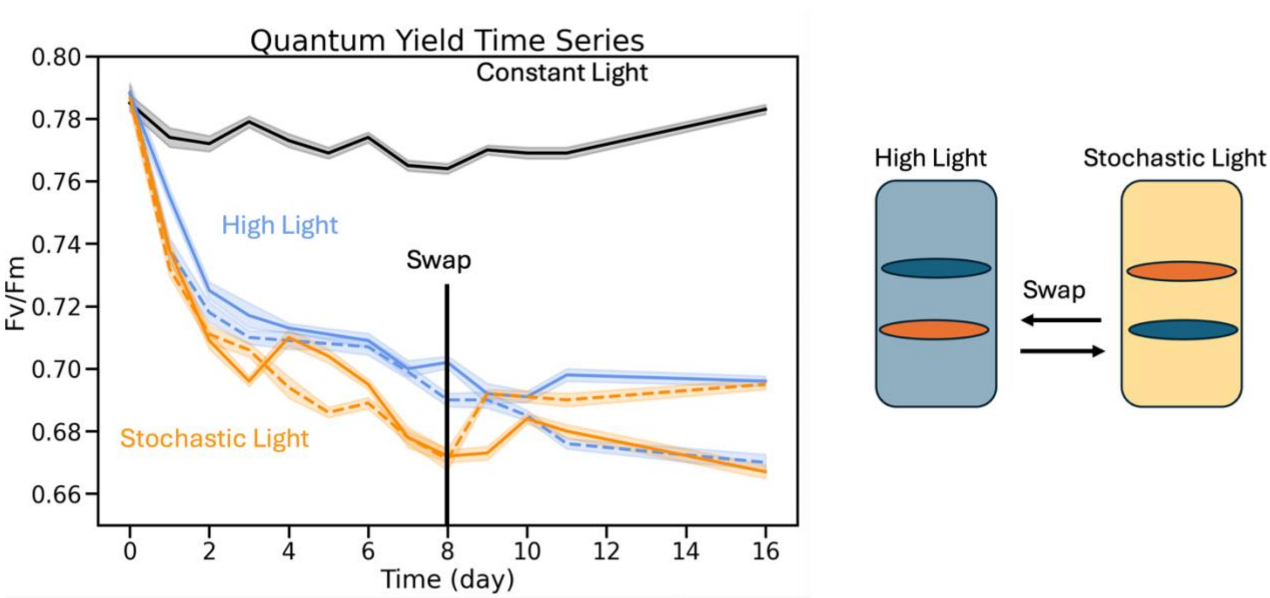

Figure 1: Time series of maximum quantum yield of PSII reveals distinct physiological responses. Dashed lines represent samples that underwent a treatment swap halfway through the experiment. Both high light and stochastic light reduce F_v/F_m relative to constant light, but the stochastic treatment drives a stronger decline. Following the treatment swap on day 8, populations transition toward the phenotype associated with the new light environment, indicating photosynthetic state plasticity and differential acclimation pathways.