growth rate:

In this study, the chlorophyll specific exponential growth rates (μ; d^−1^) vs. cumulative diel PAR (Fig Sxxx in Supplementary materials) or PUR (µmol photons m^−2^d^−1^) for two PhycoCyanin(PC)-rich cultures (056, 077) and two PhycoErythrin(PE)-rich cultures (048, 127) of \*Synechococcus\* sp. originating from the Baltic Sea were determined. Growth rates were estimated from logistic fits of chlorophyll proxy OD~680~ - OD~720~ vs. elapsed time for picocyanobacteria cultures grown at 30, 90, 180, 300, 600 or 900 peak PAR µmol photons m^−2^s^−1^ (µE); and photoperiods of 8, 12, 16, or 24 h (Fig. \@ref(fig:GrowthRatePhotoperiod)).

Analyzed phenotypes of \*Synechococcus\* sp. showed varying chlorophyll specific exponential growth rates (μ) under different photoperiod and light conditions. Three-way factorial ANOVA showed that individual factor (irradiance, photoperiod, and strain) and their interactions significantly affected the μ, estimated from logistic fits of chlorophyll proxy OD~680~ - OD~720~ vs. elapsed time (ANOVA, \*p\* < 0.05 for all; Table S3). All tested strains were able to grow even under peak PAR 900 µmol photons m^−2^s^−1^ and 24 h photoperiod, except PE-rich\_048. The highest growth rate was recorded for \*Synechococcus\* sp. PE-rich\_127 (μ = 4.5 d^−1^) and PC-rich\_056 (μ = 3.4 d^−1^) at the 180 µmol photons m^−2^s^−1^ and photoperiod of 24 h.

We also found that cumulative diel PUR consistently explains achieved μ across a matrix of photoperiods and peak PAR. Every strain showed distinct growth responses to cumulative diel PUR, depending upon photoperiod. One-way ANOVA of a three parameter model [@harrisonPhotosynthesisirradianceRelationshipsPolar1986] from μ for two PC-rich and two PE-rich cultures of \*Synechococcus\* sp. showed significant difference between model performed from pooled data and data fit across all tested photoperiods (8, 12, 16, or 24 h; ANOVA, \*p\* < 0.05, Table S4 in Supplemental material). Strains also showed distinct growth responses to cumulative diel PUR, depending upon peak PAR. In supplemental data (Fig. S5), strains generally showed peak-PAR specific responses to cumulative diel PAR or PUR, that differ from a single light response model fit to the pooled data from a strain. Exceptions were observed in the strains PC-rich\_077 and PE-rich\_048 with the peak PAR of 600 or 900 µmol photons m^−2^s^−1^, which were not significantly different from the pooled data model (Table S5 in Supplemental material). A caveat to these findings is that cumulative diel photon dose is a product of photoperiod and PAR, so the highest levels of cumulative diel photon dose are only achieved under the 600 or 900 µmol photons m^−2^s^−1^.

Growth rate saturated under increasing cumulative diel PAR for all strains however, the achieved estimates of µ~max~ varied depending upon photoperiod and peak diel PAR. Growth rates vs. cumulative diel PUR relationships, estimated for exponential phase cultures, followed similar patterns (Fig. S6 and Table Sxxx in Supplemental material).

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PUR/PAR ratio:

Changes of PUR/PAR ratio vs. cumulative diel PAR (µmol photons m^−2^d^−1^) for two PC-rich cultures (056, 077) and two PE-rich (048, 127) cultures of \*Synechococcus\* sp. grown at 30, 90, 180, 300, 600, or 900 peak PAR µmol photons m^−2^s^−1^ (µE); and photoperiods of 8, 12, 16, or 24 h were estimated (Fig. \@ref(fig:PURPARRatio)). Three-way factorial ANOVA showed that individual factor (cumulative diel PAR, phase of growth, or strain) but not the interactions of these 3 factors, affected the PUR/PAR ratio (ANOVA, \*p\* < 0.05, Table S6).

Strains also showed consistent patterns of light capture efficacy (PUR/PAR ratio) across cumulative diel PAR. The ratio of PUR/PAR decayed exponentially in relation to cumulative diel PAR, across different combinations of photoperiod and peak PAR. Although all strains followed a similar trend, the single phase exponential decay fit models varied significantly among strains during their exponential phase of growth (ANOVA, \*p\* < 0.05, Table S7). The exception was the fit of the models PE-rich\_048 and PE-rich\_127 (ANOVA, \*p\* > 0.05). During pre-stationary phase this response dampens and even disappears (ANOVA, \*p\* > 0.05, Table S7). Significant differences between the fit models for different phases of growth within all given strains with the exception of PC-rich\_056 were also noted (ANOVA; \*p\* < 0.05, Table S7). Moreover, the PUR/PAR ratio was significantly higher in the PE-rich strains under low cumulative diel PAR during their exponential phase of growth; however, decay towards a plateau close to the PC-rich strains as cumulative diel PAR increases.

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Sigma vs photondose:

In this work, we estimated the effective absorption cross section of PSII ($\sigma$~PSII~'; nm^2^ quanta^−1^) measured under diel peak PAR growth light vs. cumulative diel PAR (µmol photons m^−2^d^−1^). $\sigma$~PSII~' was estimated using FRRf induction curves using Ex~590nm~ (orange) excitation, for two PC-rich (056, 077) and two PE-rich (048, 127) cultures of \*Synechococcus\* sp. grown at 30, 90, 180, 300, 600, or 900 peak PAR µmol photons m^−2^s^−1^ (µE); and photoperiods of 8, 12, 16, or 24 h (Fig. \@ref(fig:Sigma590)). The $\sigma$~PSII~' measured under diel peak PAR growth light under Ex~445nm~ (blue) excitation vs. cumulative diel PAR was shown in Supplementary material (Fig. S10, Table S10-S11).

Similarly to the PUR/PAR ratio, three-way factorial ANOVA showed that individual factor (cumulative diel PAR, phase of growth, or strain) and their interactions, significantly affected the $\sigma$~PSII~' measured under diel peak PAR growth light under Ex~590nm~ excitation (ANOVA, \*p\* < 0.05; Table S12 in Supplemental material).

All strains showed consistent patterns of effective absorption cross section for PSII photochemistry across cumulative diel PAR. The $\sigma$~PSII~' examined a consistent, sharp exponential decay in relation to cumulative diel PAR, across different combinations of photoperiod and peak PAR. Although all strains showed this response pattern, the exponential decay fit models differ significantly among two PC-rich strains and PE-rich\_048 during their exponential phase of growth (ANOVA, \*p\* < 0.05; Table S13 in Supplemental material). During pre-stationary phase this response dampens but persists. Additionally, the significant differences between the fit models for different phases of growth within all given strains, with the exception of PE-rich\_048, were also presented (ANOVA; \*p\* < 0.05, Table S13).

The PE-rich strains showed higher $\sigma$~PSII~' under low cumulative diel PAR, and remain higher than the PC-rich strains even as cumulative diel PAR increases.

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Sig vs pigment:

Changes of effective absorption cross section of PSII ($\sigma$~PSII~'; nm^2^ quanta^−1^) measured under diel peak PAR growth light under Ex~590nm~ (orange) excitation vs. total Phyco/Chl \*a\* ratio, for PC-rich\_056, PC-rich\_077, PE-rich\_048, and PE-rich\_127 cultures of \*Synechococcus\* sp. grown at 30, 90, 180, 300, 600, or 900 peak PAR µmol photons m^−2^s^−1^ (µE); and photoperiods of 8, 12, 16, or 24 h were demonstrated (Fig. \@ref(fig:SigmaPig590)). Changes of effective absorption cross section of PSII ($\sigma$~PSII~; nm^2^ quanta^−1^) measured at the dark period under Ex~590nm~ (orange) excitation vs. total Phyco/Chl \*a\* ratio were shown in Supplementary material (Fig. S9, Table Sxxx). Also, the $\sigma$~PSII~' measured under diel peak PAR growth light under Ex~445nm~ (blue) excitation vs. total Phyco/Chl \*a\* ratio was shown in Fig. S11 and Table S14-S15.

In this work we found that $\sigma$~PSII~' showed a consistent relation to phycobilisome:chlorophyll ratio. Three-way factorial ANOVA showed that individual factor (cumulative diel PAR, phase of growth, or strain) and their interactions, significantly affected the $\sigma$~PSII~' measured under diel peak PAR growth light under Ex~590nm~ excitation relation to the total Phyco/Chl \*a\* ratio (ANOVA, \*p\* < 0.05; Table S16 in Supplemental material).

The $\sigma$~PSII~' excited through chlorophyll absorbance at Ex~445nm~ was consistently small across strains and growth conditions, since in cyanobacteria the number of chlorophyll serving PSII is nearly fixed (CITATIONS DOUG, Fig. S11). For $\sigma$~PSII~' excited through phycobilisome absorbance at Ex~590nm~, strains show consistent positive correlation with total Phyco/Chl \*a\* ratio.

Strains in exponential growth show significant scatter around this positive relation, likely related to regulatory control of $\sigma$~PSII~', beyond pigment composition. Under pre-stationary phase the relationship between $\sigma$~PSII~' and total Phyco/Chl \*a\* ratio was more consistent, suggesting an increase in reliance upon compositional regulation to control light delivery to PSII, as opposed to shorter-term regulation.

The linear fits also vary significantly among strains. The linear fit models differ significantly among PC-rich\_077 and two PE-rich strains during their exponential phase of growth. During pre-stationary phase we noted significant differences between two PC-rich strains and PE-rich\_048. Moreover, the significant differences between the fit models for different phases of growth were noted for PC-rich strains 056 and 077 (t-test; \*p\* < 0.05, Table S17).

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