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Supplementary Information for

Dynamics and functional diversity of the smallest phytoplankton on the Northeast US Shelf

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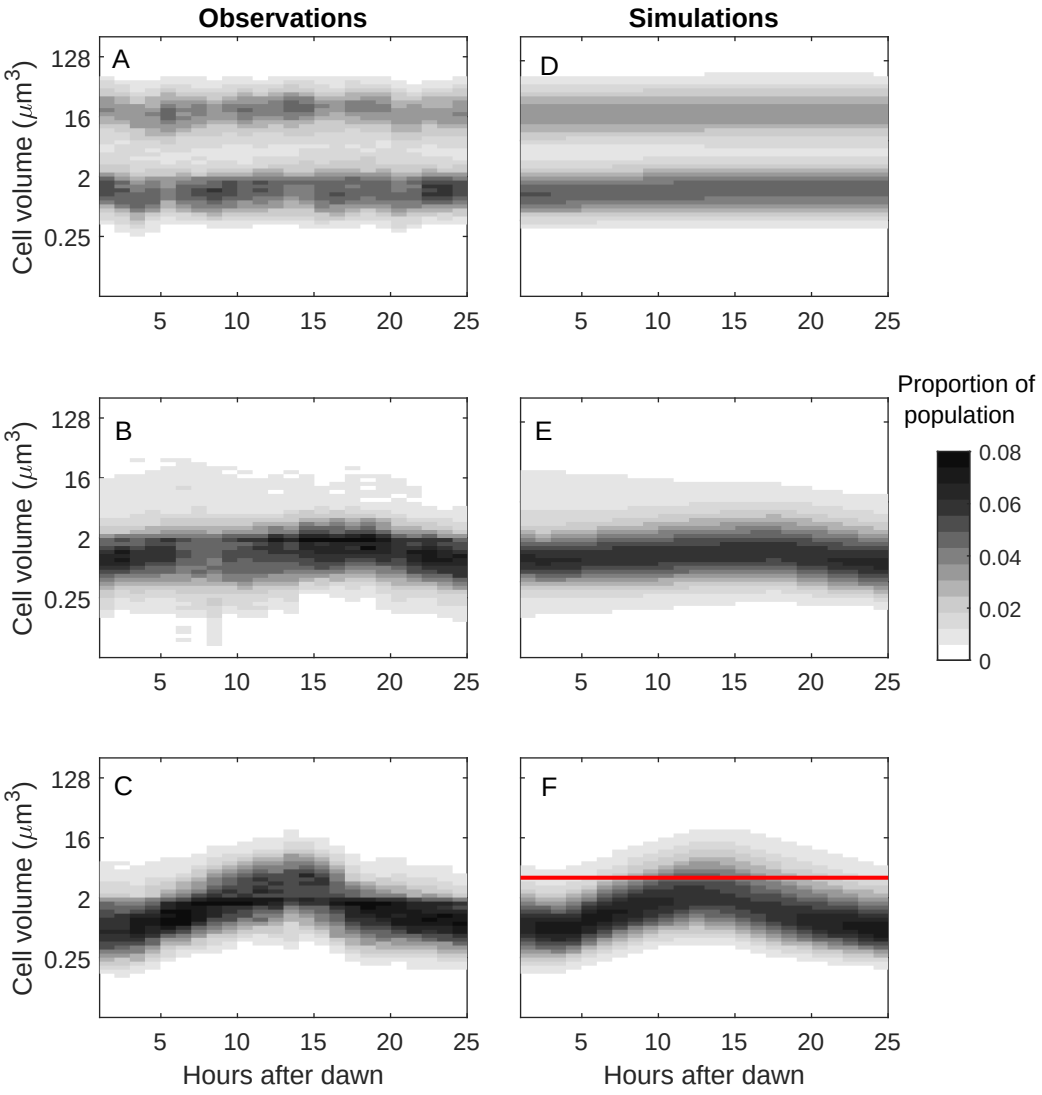

Fig. S1. Examples of the daily progression of picoeukaryote cell size distribution. Observations (left column) were made by FCB at MVCO on A) March 30, 2011, B) May 8, 2011, and C) Sept 6, 2012. We fit the model parameters to each day's data using maximum likelihood estimation, and the resulting simulations (right column) agree well with the observed dynamics. Estimates of division rate for these examples are 0.03, 0.92, and 2.65 d^{-1} respectively. The red line in panel F indicates the traditional size threshold for picoplankton (2 μm diameter, 4.19 μm^3 volume).

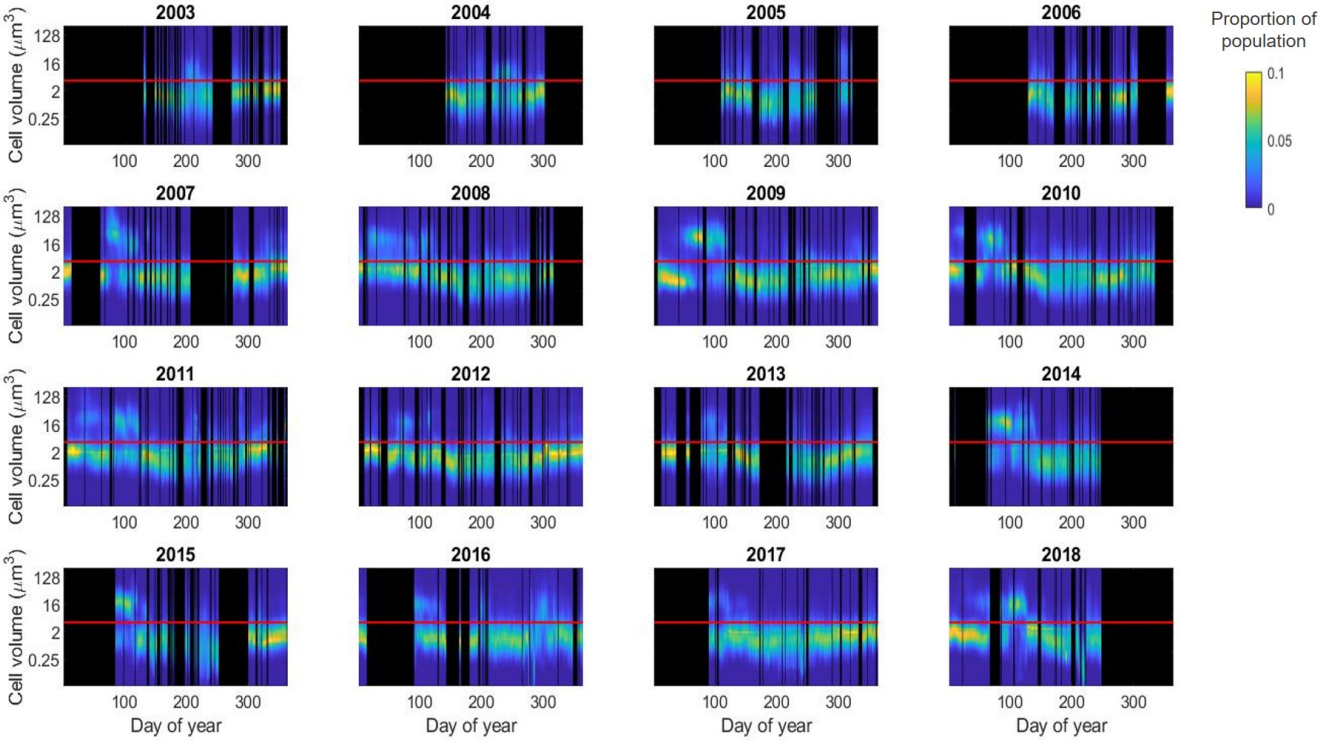

Fig. S2. Time series of size distributions. For each day of the year with data, the population's average size distribution is indicated by the heatmap. The red line indicates the traditional size threshold for picoplankton (2 μm diameter, 4.19 μm^3 volume). Black areas indicate days when data are not available.

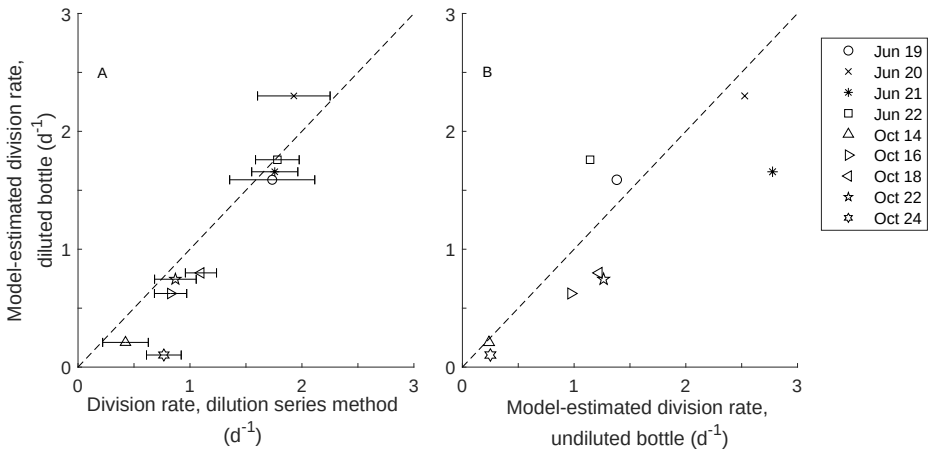

Fig. S3. A) Relationship between picoeukaryote division rate estimated by dilution series method and by the model fit to flow cytometry observations within the diluted bottles. Each experiment was carried out in triplicate in either June or October 2012. 95% confidence intervals are plotted for estimates obtained from the dilution series method. B) Comparison of model estimates of division rate for the same sample in most diluted and undiluted conditions. Identity lines are included for reference.

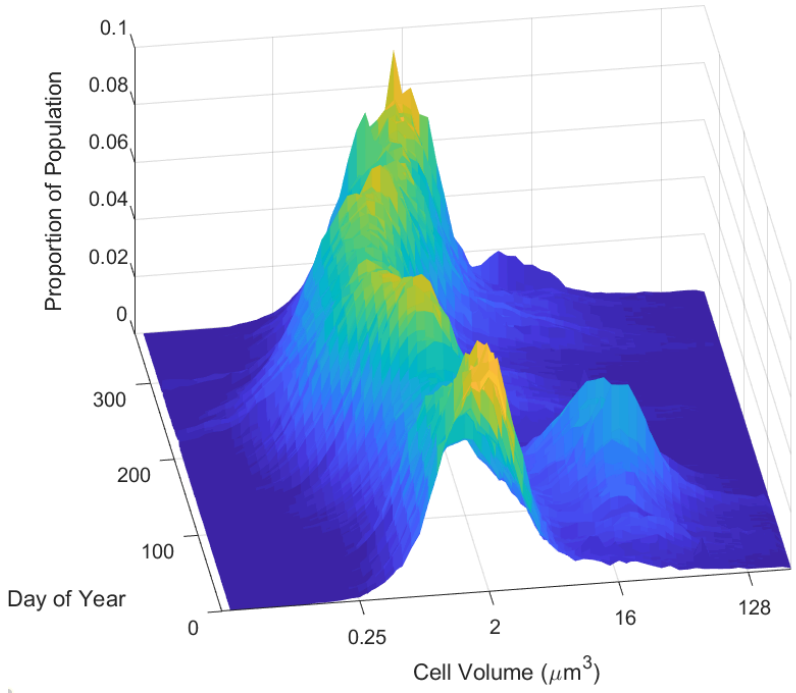

Fig. S4. Annual pattern in size distribution of picoeukaryote community. Observed size distribution at dawn, averaged for each day of the year across all years observed.

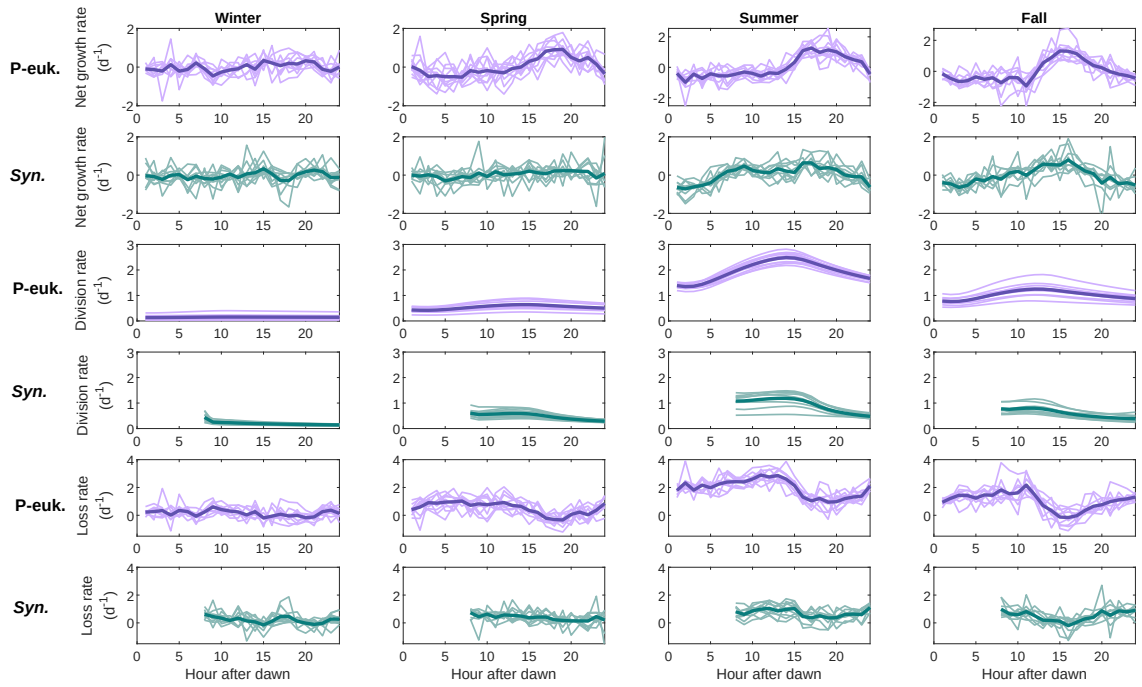

Fig. S5. Hourly vital rates for Picoeukaryotes (P-euk.) and *Synechococcus* (*Syn.*) broken down by season. Each line represents a distinct year and hourly values are averaged across all days of the year within the seasons indicated (For simplicity, Winter is defined as Dec-Feb, Spring as Mar-May, Summer as Jun-Aug, and Fall as Sept-Nov.) Years with fewer than 180 days of data are excluded; 2018 is excluded from the Fall plots. Each bold line is the average across all years considered.

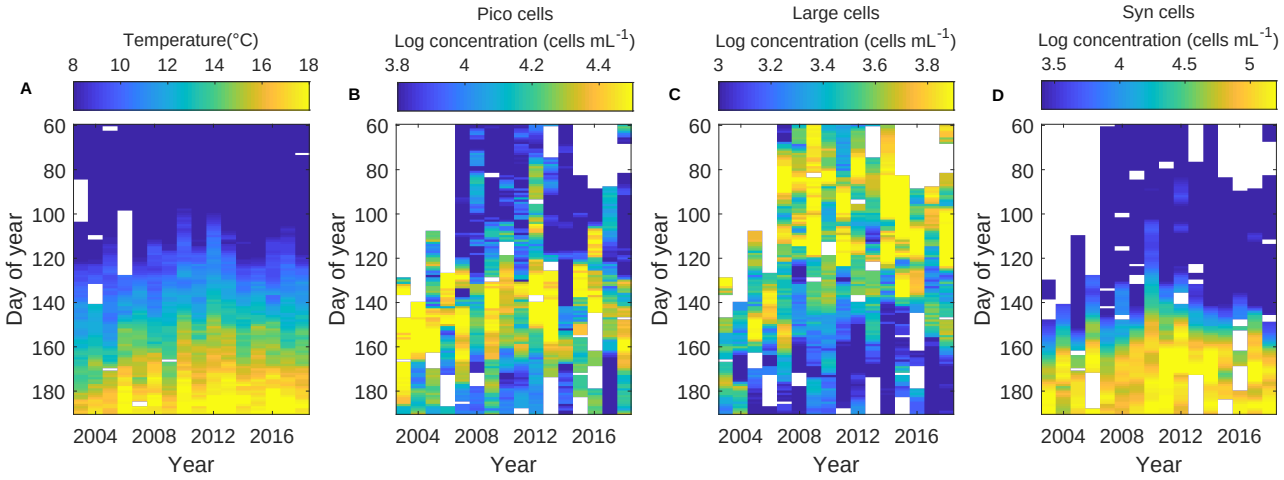

Fig. S6. Interannual variability in timing of spring transitions. For each panel, vertical axis is day of the year and horizontal axis is year in our time series. Color indicates (A) temperature, (B) concentration of eukaryotic cells smaller than 2 μm in diameter, (C) concentration of eukaryotic cells between 2 and 8 μm in diameter, and (D) concentration of *Synechococcus*. *Synechococcus* population size increases earlier in years when temperatures reaches higher values earlier. Similarly, the concentration of large picoeukaryotes drops earlier in years when temperature reach higher values earlier. The drop in larger eukaryotes corresponds to an increase in smaller eukaryote abundance.

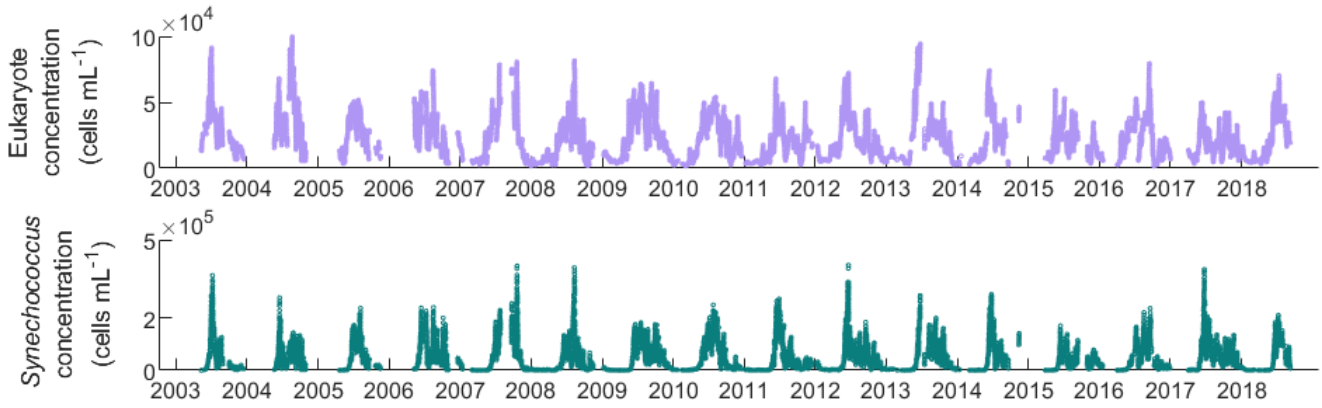

Fig. S7. Time series of observations of cell concentration for picoeukaryotes (upper) and *Synechococcus* (lower). Values are 48-hour running averages. Note that the two populations behave similarly but do not perfectly match.

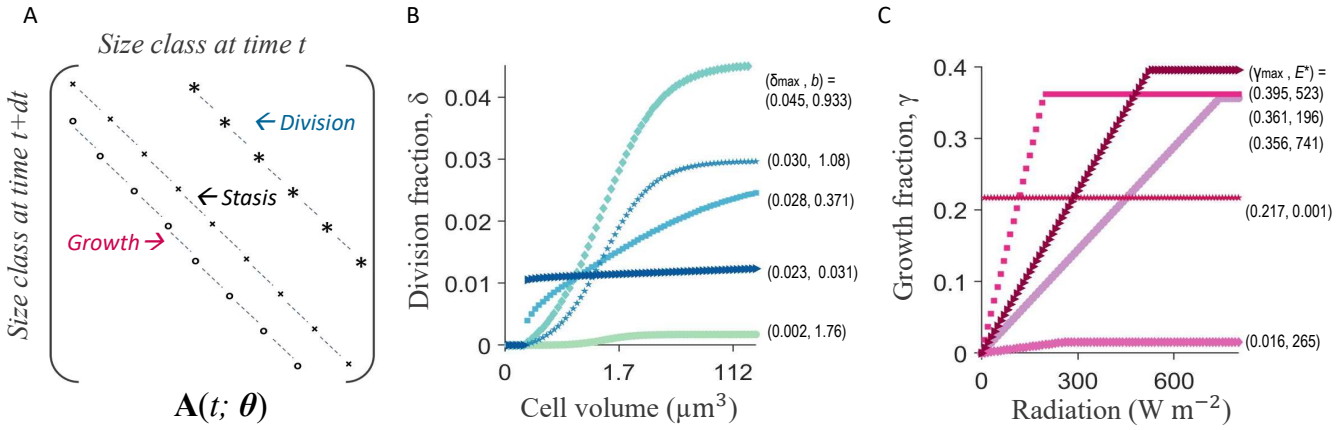

Fig. S8. A) Structure of the transition matrix, $\mathbf{A}(t; \theta)$. Terms along the diagonals are 2δ, (1-δ)(γ) and (1-δ)(1-γ) for division, growth, and stasis, respectively. All entries not occupied by a symbol are 0. Examples of B) the division fraction, δ, and C) the growth fraction, γ, as estimated for a sample of picoeukaryote observations. Parameter values are indicated to the right of each curve.

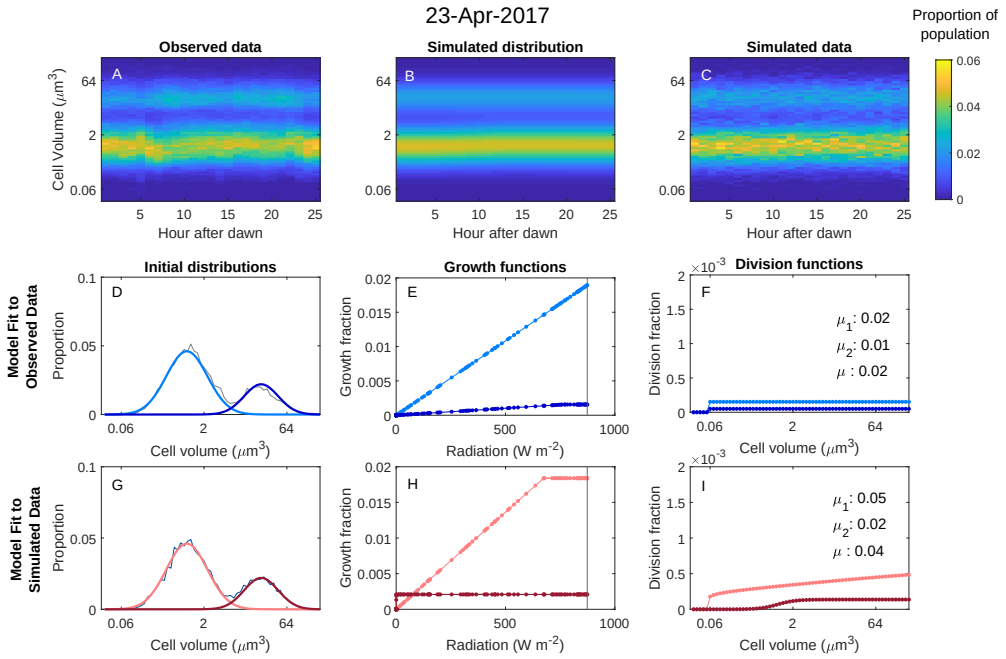

Fig. S9. Details of modeled picoeukaryote assemblage for April 23, 2017. The assemblage has a clear bimodal size distribution as is typical of many days in the early spring. A) Size distribution of small eukaryotes observed at MVCO over the course of the day. B) Size distribution of model simulation based on best-fit parameter estimates. C) Multinomial random sample from simulated size distribution (B). D) Size distribution at dawn of observations (grey line) and two subpopulations (light and dark blue lines). E) Growth functions of two subpopulations. Vertical grey line indicates maximum light level observed on this day. F) Division functions of two subpopulations with daily division rate estimates inset. μ_1 indicates the division rate for the light blue population, μ_2 is for the dark blue population, and μ is the total daily division rate for the assemblage. G-I) Results of model fit to simulated data (C). Presented in the same format as (D-F), with light and dark red lines indicating model-estimated subpopulations. Note that while the division functions in (I) and (F) have different shapes, the y-axis covers a much smaller range than on other days (Fig. S10-S11), such that all these division functions are effectively flat. Division rate estimates for the two populations and the assemblage agree well with the known values.

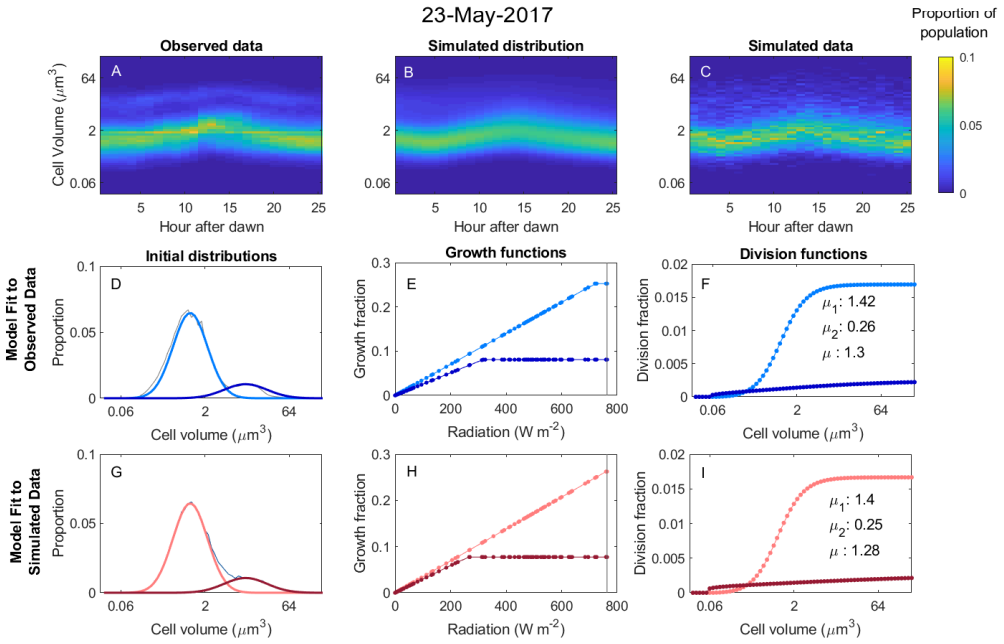

Fig. S10. Details of modeled picoeukaryote assemblage for May 23, 2017. Many days in our data set exhibit this pattern: one dominant population with either a fat tail or a second mode of larger cells. In these cases, the model fits two overlapping populations. A) Size distribution of small eukaryotes observed at MVCO over the course of the day. B) Size distribution of model simulation based on best-fit parameter estimates. C) Multinomial random sample from simulated size distribution (B). D) Size distribution at dawn of observations (grey line) and two subpopulations (light and dark blue lines). E) Growth functions of two subpopulations. Vertical grey line indicates maximum light level observed on this day. F) Division functions of two subpopulations with daily division rate estimates inset. μ_1 indicates the division rate for the light blue population, μ_2 is for the dark blue population, and μ is the total daily division rate for the assemblage. G-I) Results of model fit to simulated data (C). Presented in the same format as (D-F), with light and dark red lines indicating model-estimated subpopulations. Division rate estimates for the two populations and the assemblage agree well with the known values.

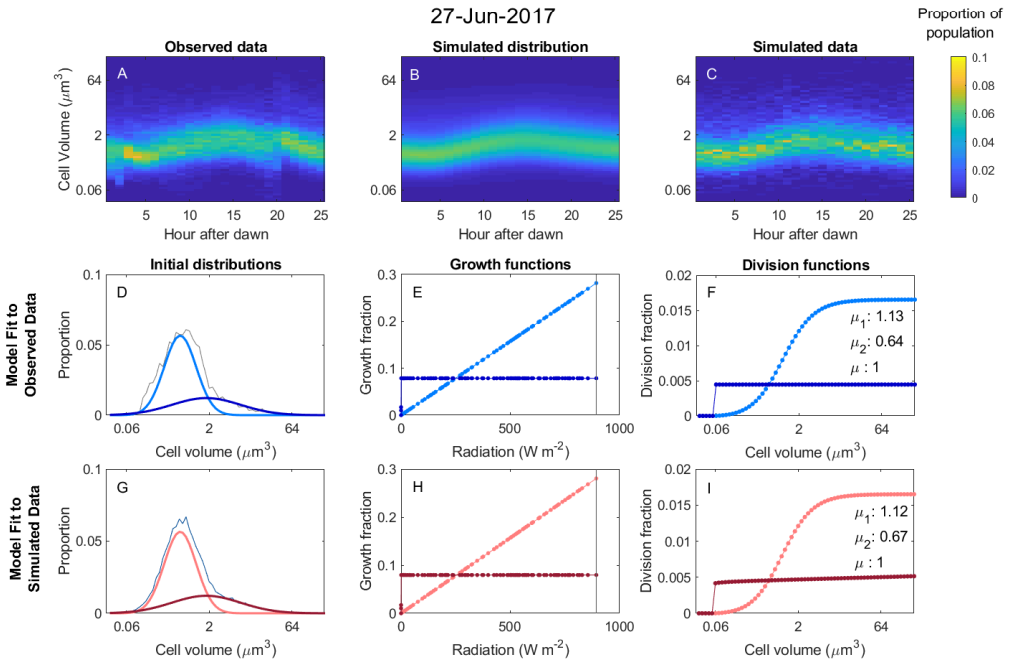

Fig. S11. Details of modeled picoeukaryote assemblage for June 27, 2017. This is an example of a day where we see one dominant population with a second background population spanning nearly the entire range of possible cell volumes. This may help to capture the tail of the distribution and to accommodate noise in the observations. A) Size distribution of small eukaryotes observed at MVCO over the course of the day. B) Size distribution of model simulation based on best-fit parameter estimates. C) Multinomial random sample from simulated size distribution (B). D) Size distribution at dawn of observations (grey line) and two subpopulations (light and dark blue lines). E) Growth functions of two subpopulations. Vertical grey line indicates maximum light level observed on this day. F) Division functions of two subpopulations with daily division rate estimates inset. μ_1 indicates the division rate for the light blue population, μ_2 is for the dark blue population, and μ is the total daily division rate for the assemblage. G-I) Results of model fit to simulated data (C). Presented in the same format as (D-F), with light and dark red lines indicating model-estimated subpopulations. Division rate estimates for the two populations and the assemblage agree well with the known values.

Table S1. Estimated division and grazing rates of picoeukaryotes (p-euk) and *Synechococcus* (*Syn*) from dilution series experiments. In cases where experiments were continued for 48 hours, values for the second day are reported in the second line of the entry. Values in parentheses indicate experiments where no trend in net growth rate was observed across treatments. These estimates were not used in (1), but may indicate either negligible grazing rates, inhibition of picoplankton growth by dilution (see Discussion), or failure to dilute *Synechococcus* to levels that reduce grazing pressure. All division rates for the picoeukaryotes were obtained using a linear (one-phase) estimation method.

Experiment Start Date	p-euk Division Rate (d^{-1})	p-euk Grazing Rate (d^{-1})	*Syn* Division Rate (d^{-1})	*Syn* Grazing Rate (d^{-1})
1. June 19, 2012	1.73	1.54	(0.30)	(0)
	N/A	N/A	N/A	N/A
2. June 20, 2012	1.93	1.37	(0.58)	(0)
	N/A	N/A	N/A	N/A
3. June 21, 2012	1.76	0.48	(0.46)	(0)
	N/A	N/A	N/A	N/A
4. June 22, 2012	1.78	1.30	(0.44)	(0)
	0.79	1.23	0.72	1.22
5. Oct 14, 2012	0.42	0.57	(0.41)	(0)
	0.97	1.93	(0.30)	(0)
6. Oct 16, 2012	(0.83)	(0)	(0.25)	(0)
	N/A	N/A	N/A	N/A
7. Oct 18, 2012	1.10	0.40	0.63	0.26
	1.15	1.12	0.53	0.33
8. Oct 22, 2012	0.87	0.06	0.69	0.08
	1.42	1.05	0.77	0.26
9. Oct 24, 2012	0.77	0.15	0.53	0.05
	0.45	0.81	0.76	0.28

References

1. KR Hunter-Cevera, et al., Diel size distributions reveal seasonal growth dynamics of a coastal phytoplankter. *Proc Natl Acad Sci USA* **111**, 9852–9857 (2014).