Linkages between surface phytoplankton and bottom oxygen in the Chesapeake Bay

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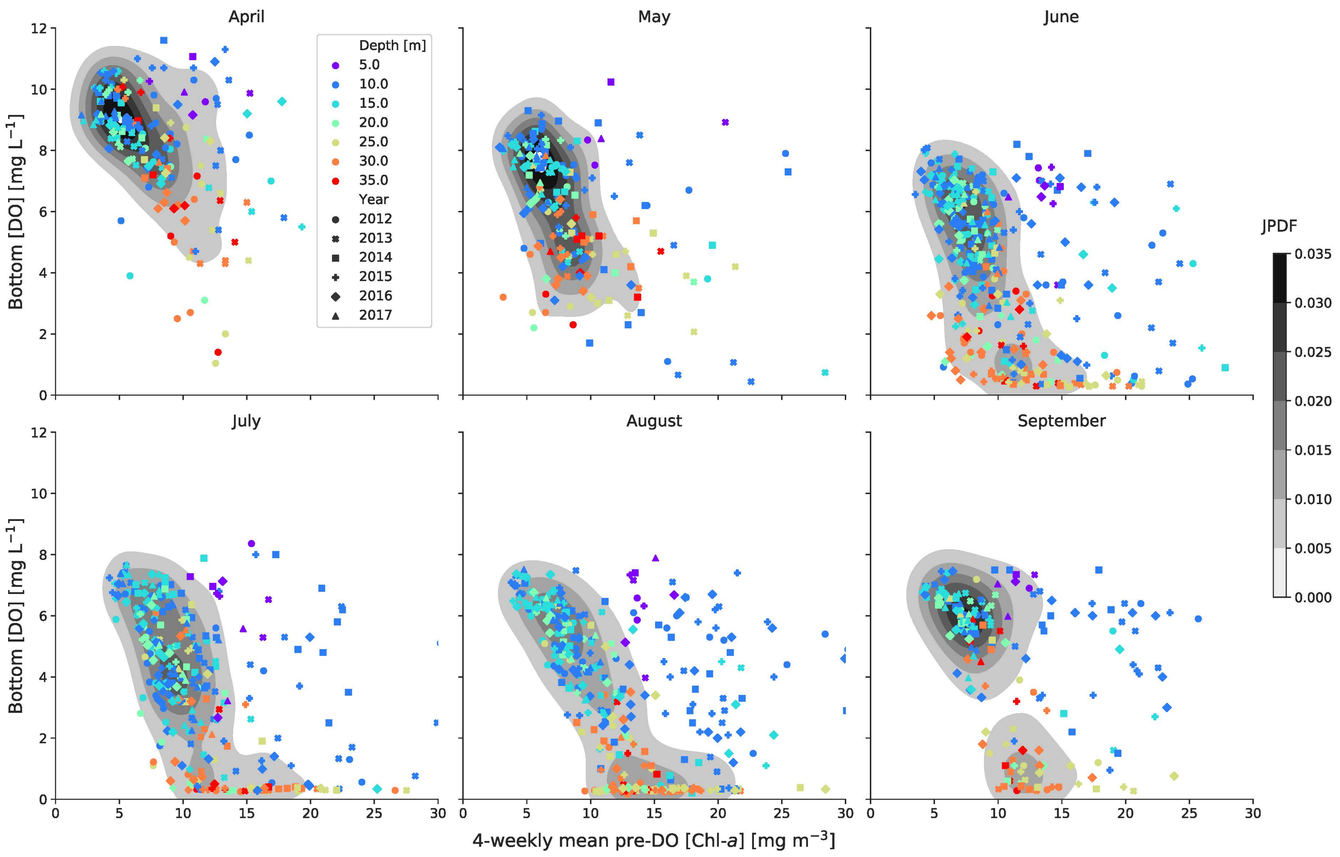
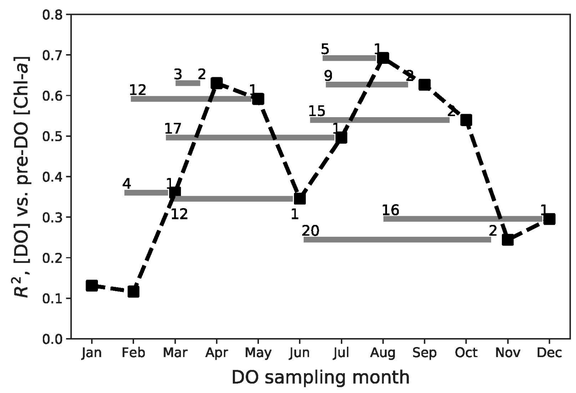
- Expanding hypoxia, along with ocean warming and ocean acidification, is considered one of the three primary ocean consequences of rising atmospheric CO_2.
- In coastal waters, the primary cause of rising hypoxia is generally attributed to eutrophication which promotes phytoplankton growth and subsequent benthic decay of phytoplankton-derived organic matter.
- Although the correlation between hypoxia and nutrient loadings was widely demonstrated, direct evidence showing linkages between hypoxia and phytoplankton has been infrequently reported.
- Here we show such linkages in the Chesapeake Bay using high-resolution time series of satellite-derived chlorophyll data.

Influence of Surface Phytoplankton on Bottom Oxygen



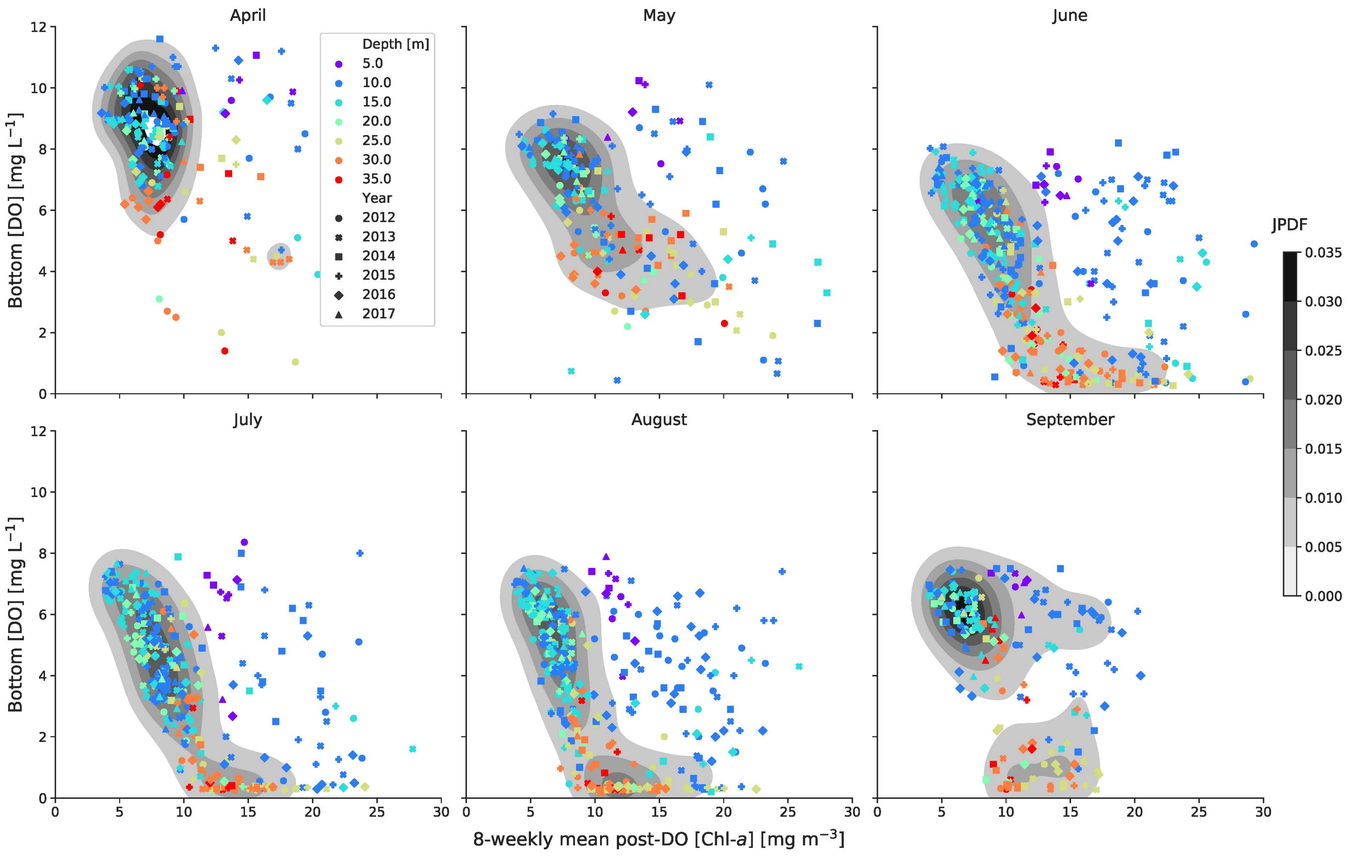
Relationship between dissolved oxygen concentration, [DO], at the bottom and 4-weekly mean pre-DO [Chl-a] at the surface in the Chesapeake Bay during main hypoxia season. Data are categorized by year and bottom depth of each station. JPDF, joint probability density function generated from the kernel density estimation; the unit is probability per unit area in the plane defined by the x- and y-dimensions.

- At stations where both vertical mixing and particulate organic sinking flux are limited, the optimal correlation coefficient, R^2, between bottom [DO] and pre-DO [Chl-*a*] exhibits a bimodal seasonal variation with two maxima in spring and summer, respectively.
- These two peaks represent seasonal hotspots of sinking POM flux associated with zooplankton fecal pellets and sinking diatoms in spring, and marine snow in late summer.
- The strong correlation between bottom [DO] and satellite-derived pre-DO [Chl-a] attests that sinking of phytoplankton-derived organic matter plays a major role in fueling the consumption of bottom oxygen.

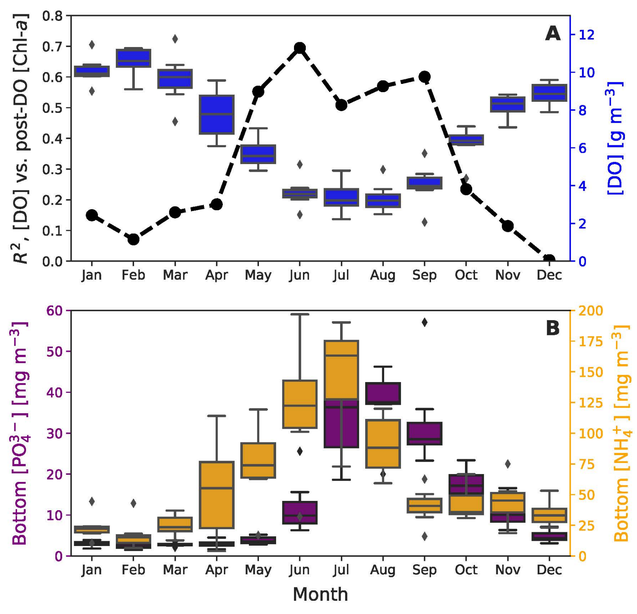


Optimal correlation between [DO] and mean pre-DO [Chl-a] computed for various duration and time lags at 30 stations deeper than 10 m in the Chesapeake Bay. Gray horizontal bars to the left of R^2 data points denote the duration over which the mean pre-DO [Chl-a] values are calculated; numbers on the bar represent the starting and ending weeks of the duration.

Feedback of Bottom Hypoxia on Surface Phytoplankton



Same as above except for 8-weekly mean post-DO [Chl-a].



(**A**) Monthly statistics of bottom [DO] and correlation between [DO] and 8-weekly mean post-DO [Chl-a], and (**B**) monthly statistics of nutrient concentrations. The box shows the quartiles of each monthly dataset while the whiskers extend to show the rest of the distribution, except for points that are determined to be "outliers" using a method that is a function of the inter-quartile range.

- The correlation between bottom [DO] and 8-weekly mean post-DO [Chl-a] exhibits one peak in summer.
- The timing matches the period with lowest bottom [DO], as well as the increased concentrations of phosphate and ammonium.
- The correlation between bottom [DO] and post-DO [Chl-a] substantiates that bottom hypoxia enhances surface algal growth by increasing the efficiency of nutrient recycling, thereby exacerbating the hypoxia problem.

Conclusions

- This study provides direct evidence of the strong coupling between surface algae and bottom oxygen in the Chesapeake Bay.
- The satellite-derived [Chl-a] provides a robust synoptic indicator of upcoming changes in bottom water oxygen demand.
- We anticipate that combining high-quality satellite [Chl-a] data with physical predictive models capable of modeling changes in oxygen supply can yield superior hypoxia forecasts than with the models alone.

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