20 Years Of Pigment Data Suggests Regional Shift In Energy Supply To Phytoplankton Communities In The Western Antarctic Peninsula

Quintin Diou-Cass[1], Nicole Waite[1], Oscar Schofield[1]

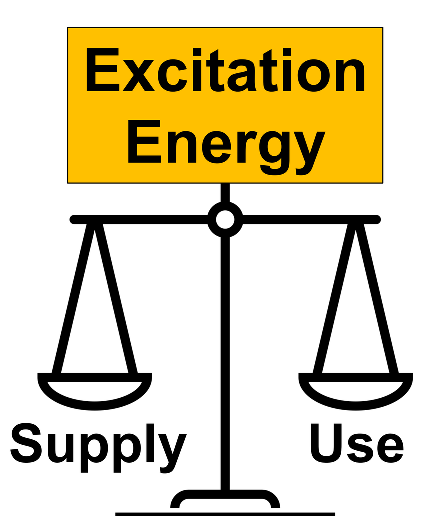
[1]Department of Marine and Coastal Sciences, Rutgers University, Piscataway, New Jersey 08854

Abstract

In the coastal regions of the Western Antarctic Peninsula (WAP), a cause-and-effect cascade is theorized between the prevailing climate and surface ocean light availability, where the extent and duration of seasonal sea ice regulates the surface ocean mixed layer depth (MLD), controlling the overall supply of incoming irradiance to the light-limited phytoplankton of the WAP. While this theory is supported by observational correlations that show regional differences in phytoplankton biomass trends, no direct physiological evidence exists for this occurrence, other than light-limitation in the phytoplankton themselves. In this analysis, we use HPLC pigment data from both the global SeaBASS database and 20 years of summer cruise data from the Palmer LTER to explore whether the relative proportion of photoprotective carotenoids in phytoplankton communities (PPC:Chla) can serve as a photophysiological signature for this change. We first asses whether photoprotective carotenoids are a reasonable signature of acclimation to differing energy supplies by looking at average PPC:TChla across latitudinal subregions that represent different light environments. We then examine PPC:Chla over a 20-year period of ecosystem change in the coastal WAP, where regional shifts in light availability are expected, to see if any long-term trends can be discerned.

Our results find an apparent latitudinal trend in averaged PPC:TChla consistent with expected differences in incoming irradiance for ecosystem on a latitudinal gradient. This supports photoprotective carotenoids as a viable signature for assessing averaged differences (or changes) in energy supply. Our results in the WAP show a discernable increase in PPC:Chla over the peninsula as a whole, driven by stronger upward trends in the northern, shelf, and slope subregions. These trends suggest an overall increase in energy supply to the system, one that must be detrimental enough in certain regions to warrant enhanced photosynthetic protection. This supports the theory that climate-driven changes in sea ice and the MLD have altered light availability for phytoplankton in the WAP and shifted their photophysiological state significantly. Future work in this area will need to explore the mechanisms and effects of this change in greater detail.

Background



Phytoplankton Want to Maintain Balance

Pigments in Phytoplankton

- To balance energy supply and use, phytoplankton will alter their pigment concentrations depending on the average light intensity in their environment
- Photoprotective Carotenoids (PPC) are pigments that dissipate excitation energy, and their proportion relative to chlorophyll will increase when there is an over-abundance of light energy supplied to the phytoplankton
- PPCs are light-dependent components of photophysiology that serve a distinct purpose and react accordingly to environmental energy supply

Does PPC:TChla reflect inherent differences in light supply between latitudinal subregions?

Biomass Changes in the WAP

- Multidecadal shifts in phytoplankton biomass have been observed across the WAP, where biomass is decreasing in the North and increasing in the South
- These trends are believed to be caused by decreases in sea ice over the past 30 years that alter the mixed layer depth and in turn the average light availability to phytoplankton

Has PPC:Chla changed in the WAP over time? Are there any regional differences in trends?

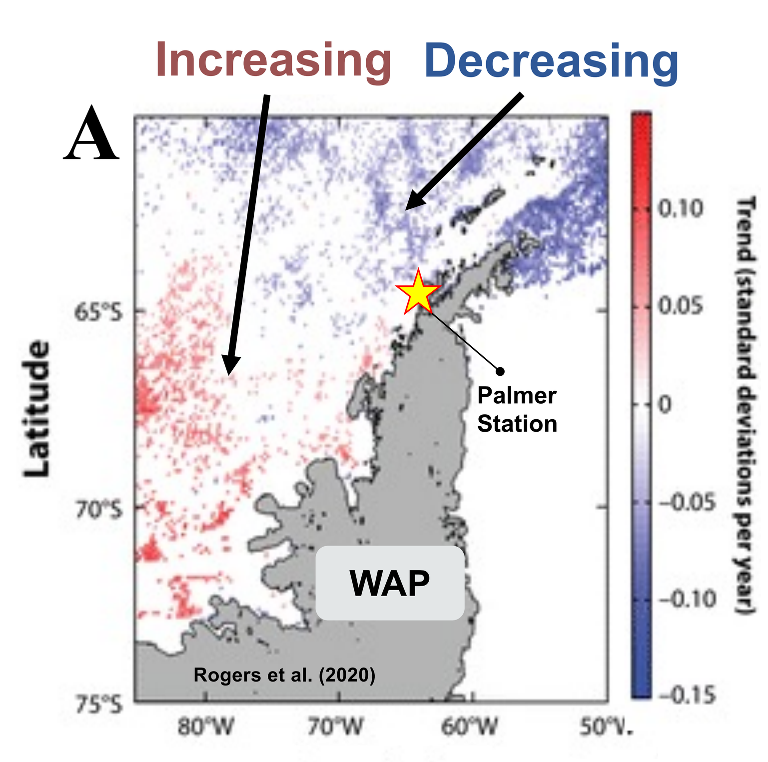


Figure A: Regional depiction of trends in satellite-derived chlorophyll-a anomalies from 1997-2015. Figure modified from ***Rogers et al. (2020)***.

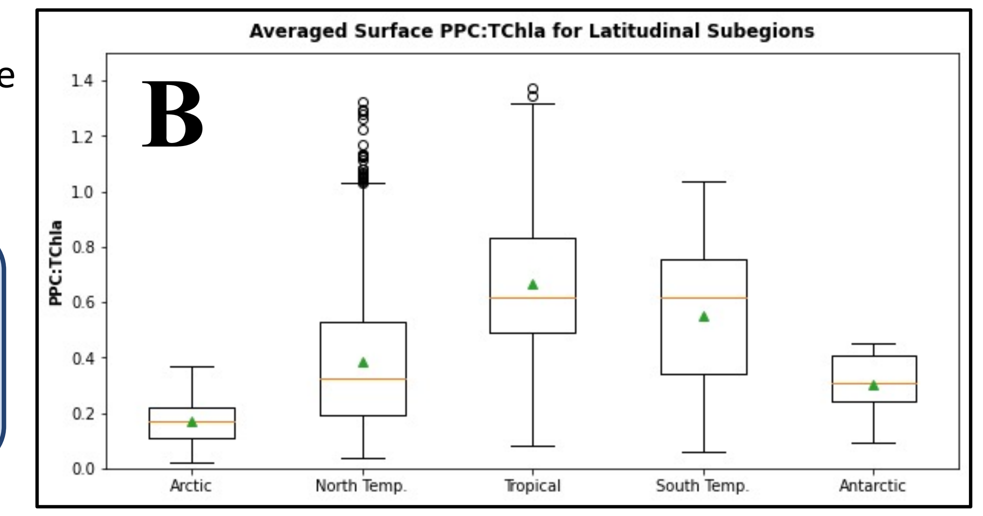
Results

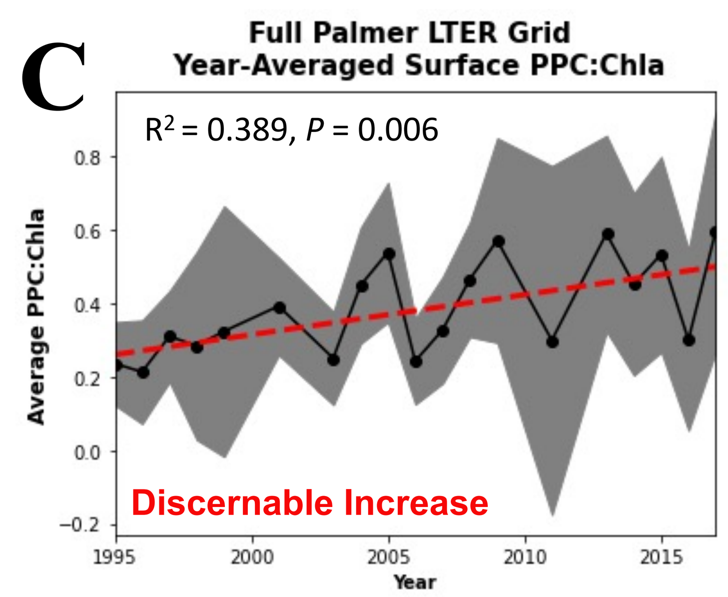
Average PPC:TChla Shows Latitudinal Trends

- High-light regions like the tropics have greater/more variable PPC:TChla on average than low-light polar regions

Signatures of region-specific adaptation to ambient light supply are evident in relative proportions of photoprotective carotenoids

Figure B: Boxplots of PPC:TChla for latitudinally-defined subregions. Green triangles indicate the mean. Sourced from Nasa SeaBASS HPLC data



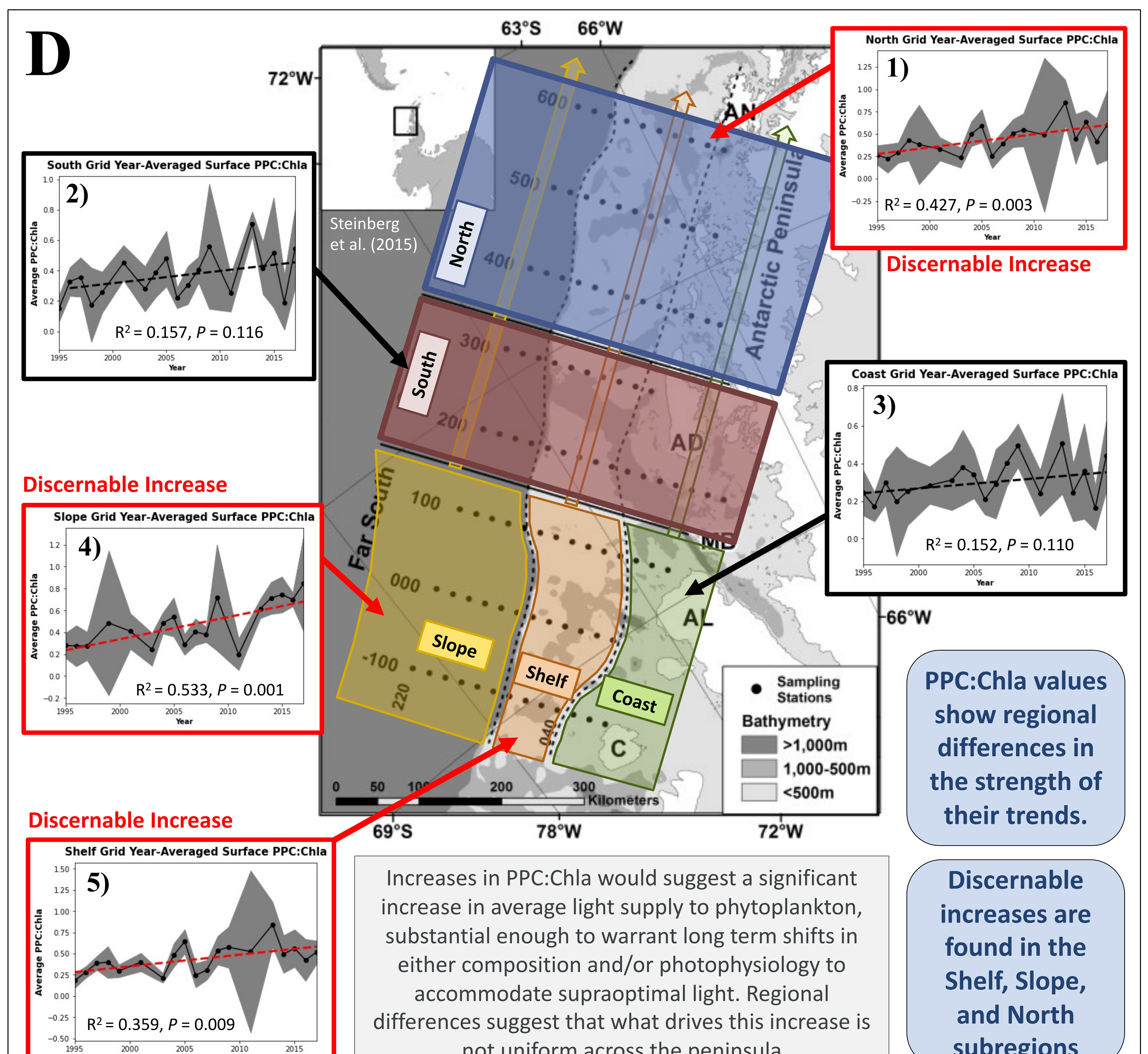


Shifted PPC:Chla in the WAP

- OLS regression analysis suggests increasing PPC proportions across the WAP as a whole
- Grid-wide trend is driven by regional differences in temporal trends (see Figure D)

PPC:Chla values along the WAP express a discernable increase averaged across the LTER grid

Figure C: Full grid, year-averaged surface PPC:Chla trend between 1995 and 2017. Dashed red line indicates Ordinary Least Squares (OLS) linear regression. R^2 and *p*-value from OLS are displayed. Grey area indicates +/- one standard deviation



PPC:Chla values show regional differences in the strength of their trends.

Discernable increases are found in the Shelf, Slope, and North subregions

Increases in PPC:Chla would suggest a significant increase in average light supply to phytoplankton, substantial enough to warrant long term shifts in either composition and/or photophysiology to accommodate supraoptimal light. Regional differences suggest that what drives this increase is not uniform across the peninsula

Figure D: Region-specific trends of year-averaged surface PPC:Chla in the Palmer LTER WAP grid between 1995 and 2017. Dashed red lines indicate Ordinary Least Squares (OLS) linear regressions with significant (alpha=0.05) upward trends. R^2 and *p*-values from OLS are displayed. Grey areas indicate +/- one standard deviation. Baseline map and subregion distinctions sourced from ***Steinberg et al. (2015)***

Materials and Methods

Datasets:

Data for this analysis was obtained from the SeaWiFS Bio-optical Archive and Storage System (SeaBASS) database (accessed on January 28th, 2022, filtered for HPLC data) and the Palmer Long-Term Ecological Research (LTER) project dataset. Pigment sums and ratios for both datasets were made following calculations and definitions in Table 4 and 5 of *S.B. Hooker et al., (2012). The Fifth SeaWiFS HPLC Analysis Round-Robin Experiment (SeaHARRE-5) Rep. Greenbelt, MA, NASA Goddard Space Flight Center, 1-108.* Both datasets were filtered to select for surface data and quality controlled for outliers and erroneous data.

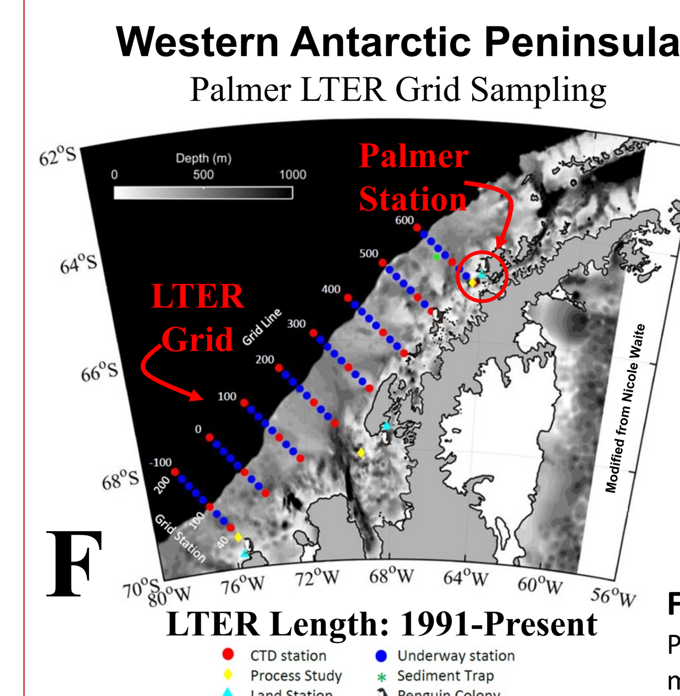
E

Region	Latitudinal Range	Sample Size (n)
Arctic	80°N - 55°N	n=364
N Temp.	40°N - 20°N	n=2948
Tropical	10°N - 10°S	n=463
S Temp.	20°S - 40°S	n=120
Antarctic	55°S - 80°S	n=23

Figure E: Latitudinal ranges and samples sizes for subregions used in global surface PPC:TChla comparison

Latitudinal Comparison:

SeaBASS data for the latitudinal comparison was divided into subregions as defined in Figure E by latitudinal ranges to represent ecosystems with inherently different energy supplies.



Palmer LTER:

Data from the Palmer LTER was collected annually in peak austral summer (January) following the grid shown in Figure F (with slight variations over time). HPLC analyses were conducted on upper water column (top 100m) samples at CTD stations along the grid. The LTER grid is broken up into 9 distinct subregions: North, South, Far South, and Coast, Shelf, Slope. Regional calculations were made by averaging surface values within the subregions within individual years. The Far South subregion was removed from this analysis due to insufficient sampling over the full time period

Figure F: A map of the predominant sampling grid conducted by the Palmer LTER's annual expedition in peak austral summer. Figured modified from Nicole Waite.

Conclusion

Coastal WAP phytoplankton show region-specific, long-term increases in relative proportions of photoprotective carotenoids during peak summer, suggesting increased light supply to the algae

Future Directions

What drives the regional differences in PPC:Chla trends?

Deciphering How Altered Light Availability Effects The Phytoplankton In Greater Detail

- How has the shift in energy supply altered phytoplankton growth rates ?
- What are the rate constants of photoacclimation in Antarctic phytoplankton species?
- What affects does altered light availability have on phytoplankton community composition?

Acknowledgments

The analysis was funded as part of the Palmer Long-Term Ecological Research (LTER) project. Acknowledgments should be given to Oscar Schofield for his intellectual contributions and support of the project, and to Nicole Waite for providing the curated LTER dataset