Characterization of phytoplankton assemblages in the western Arctic seas based on pigment composition and phytoplankton light absorption spectra

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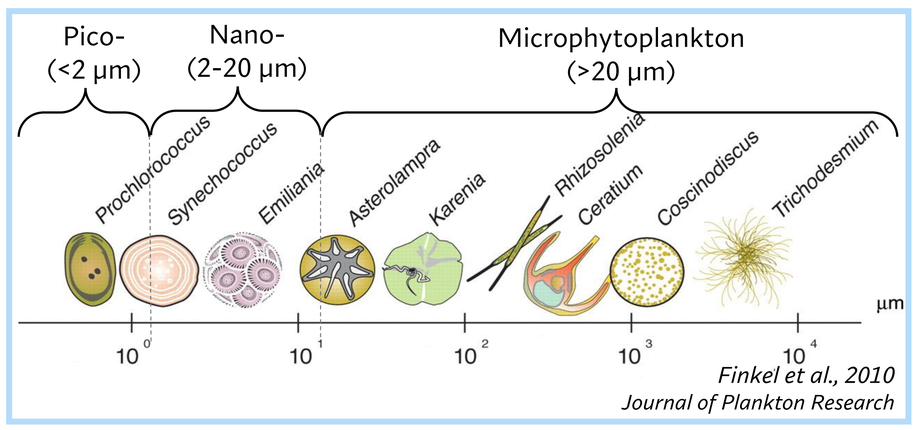
Background

- Phytoplankton community composition affects marine food web functioning, biogeochemical cycling, and carbon export
- Specific pigments can be attributed to basic cell-size classes of phytoplankton: pico-, nano-, and microphytoplankton
- The spectral absorption coefficient of phytoplankton, a_{ph}, depends on pigment composition, cell size, and intracellular pigment concentration (pigment-packaging)
- Several optically-based methods to study phytoplankton community composition have been developed for lower latitude regions
- Concurrent measurements of phytoplankton pigment concentrations and phytoplankton absorption spectra were collected in the western Arctic Seas and analyzed to investigate the ability of absorption measurements to discriminate pigment-based communities
- A diagnostic pigment analysis (DPA) was developed for our Arctic dataset; its performance was evaluated and compared with the results of previous DPAs when applied to our Arctic dataset
- The proposed Arctic-specific approach is derived solely from Arctic data of a_{ph} and pigments, and can be applied to in situ and remotely sensed multispectral and hyperspectral data
- We offer a tool to investigate climate-related impacts on Arctic phytoplankton communities which is imperative given ongoing unprecedented environmental changes



Data Collection

- Four field expeditions in the Chukchi and Beaufort Seas
- Discrete water sampling (< 5 m)
- Phytoplankton pigments (HPLC, fluorometry) and absorption (filter-pad spec. technique, IS configuration)
- Quality control based on absorption and determinations of chlorophyll *a*
- Pigment dataset (N = 134) and matchup dataset of a_{ph} and pigments (N = 93)

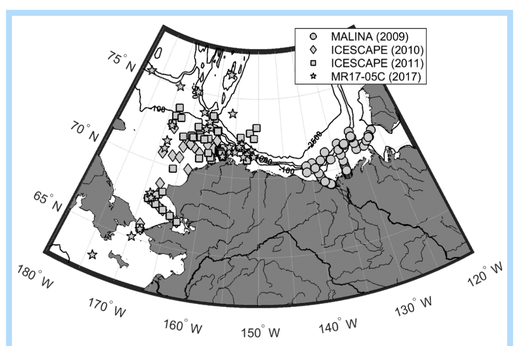


Figure 1. Map of sampling locations in the Chukchi and Beaufort Seas during the four Arctic expeditions as indicated. Isobaths in meters.

Diagnostic Pigment Analysis

- Multiple linear regression (MLR) using six phytoplankton pigments retrieved via HPLC
- Fractional contribution of each basic size class determined using a modified method from Uitz et al. (2006) and results of MLR:

$$f_{micro} = \frac{1.99(\text{Fucoxanthin}) + 1.05(\text{Peridinin})}{\Sigma DP}$$

$$f_{nano} = \frac{1.18(\text{Alloxanthin}) + 2.15(19'\text{-Hexanoyloxyfucoxanthin})}{\Sigma DP}$$

$$f_{pico} = \frac{2.33(\text{Zeaxanthin}) + 1.93(\text{Total Chlorophyll-b})}{\Sigma DP}$$

ΣDP is the weighted sum of all pigments

- Phytoplankton size classes are produced by visualizing f_{micro}, f_{nano}, and f_{pico} in ternary plot

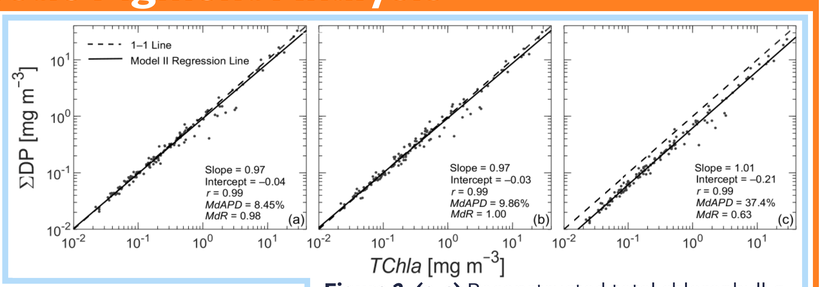
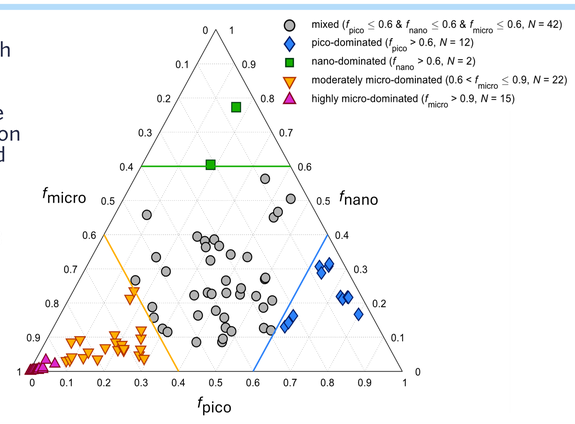


Figure 2. (a-c) Reconstructed total chlorophyll *a* concentration (ΣDP) calculated from a diagnostic pigment analysis (DPA) vs. measured *TChla* for 134 samples of pigment dataset. DPA models are: (a) this study, (b) Fujiwara et al. (2014, *Biogeosciences*) (Chukchi Sea), and (c) Uitz et al. (2006, *JGR: Oceans*) (global database excluding Arctic). In each panel, the solid line represents regression fit to the ΣDP vs. *TChla* data and the dashed line represents the 1:1 relationship. Statistics include slope and intercept of Model II regression line, Pearson's correlation coefficient (r) for log-transformed data, and median absolute percent difference (*MdAPD*) and median ratio (*MdR*) for untransformed data.

Results

Figure 3 (right). Ternary diagram with results from the diagnostic pigment analysis showing the fractional contribution of micro-, nano-, and picophytoplankton size classes to total chlorophyll *a* concentration for 93 samples within matchup dataset. Colored lines represent the boundaries used to classify the samples into phytoplankton size classes.



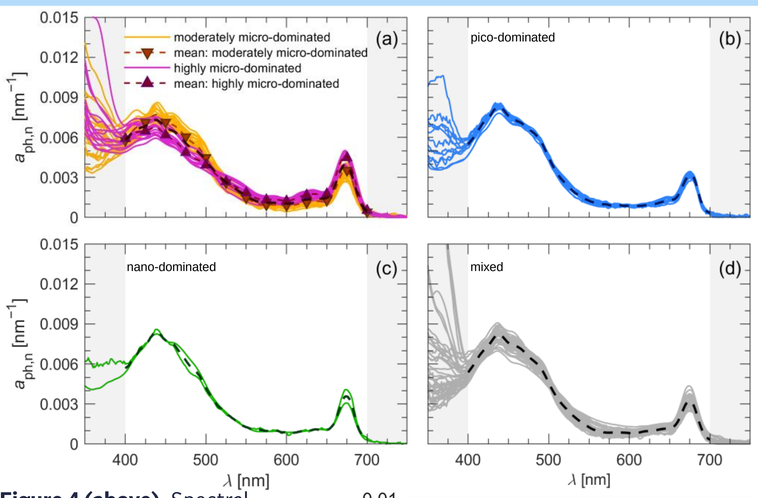


Figure 4 (above). Spectral absorption coefficient of phytoplankton normalized to the spectral integral from 400 to 700 nm, $a_{ph,n}(\lambda)$, for (a) micro-dominated, (b) pico-dominated, (c) nano-dominated, and (d) mixed samples. The micro-dominated samples in (a) are additionally separated into two subclasses, moderately micro-dominated and highly micro-dominated, as indicated in the legend. Dashed lines in each panel represent the mean spectrum for a given phytoplankton size class.

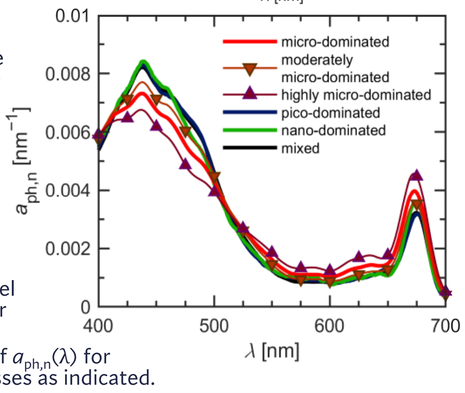


Figure 5 (right). Mean spectra of $a_{ph,n}(\lambda)$ for different phytoplankton size classes as indicated.

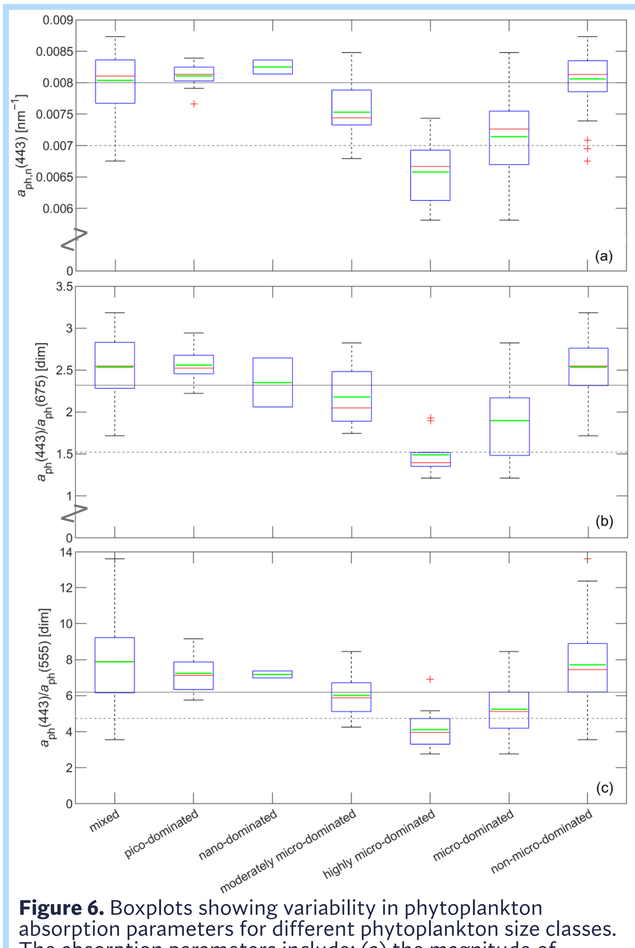


Figure 6. Boxplots showing variability in phytoplankton absorption parameters for different phytoplankton size classes. The absorption parameters include: (a) the magnitude of normalized phytoplankton absorption coefficient $a_{ph,n}(\lambda)$ at 443 nm; (b) the blue-to-red band ratio of the phytoplankton absorption coefficient, $a_{ph}(443)/a_{ph}(675)$; and (c) the blue-to-green band ratio of the phytoplankton absorption coefficient, $a_{ph}(443)/a_{ph}(555)$. For each class, the boxes show the range from the 25th (bottom of box) to 75th (top of box) percentile with whiskers extending to the non-outlier minimum and maximum values. The plus signs outside the whiskers depict outliers defined as more than 1.5 times the interquartile range value away from the non-outlier maximum or minimum. Solid grey lines denote the threshold above which a sample is classified as non-micro-dominated (below this threshold the sample is classified as micro-dominated), dashed grey lines denote the threshold above which the sample is classified as moderately micro-dominated (below this threshold the sample is classified as highly micro-dominated), red lines denote median values, and green lines denote mean values.

Table 1. The number of successful classifications into micro- and non-micro-dominated phytoplankton size classes based on the three phytoplankton absorption parameters, $a_{ph,n}(443)$, $a_{ph}(443)/a_{ph}(675)$, and $a_{ph}(443)/a_{ph}(555)$ are shown. The classification of samples by the diagnostic pigment analysis (DPA) from this study has been used as the reference for the purpose of these success-rate determinations.

		Samples classified by the DPA (N = 93)	
		Non-micro-dominated (N = 56)	Micro-dominated (N = 37)
Samples classified by $a_{ph}(\lambda)$-based parameters	$a_{ph,n}(443)$ Total successful classifications: N = 66 (71%)		
	Non-micro-dominated (N = 36)	64%	18%
	Micro-dominated (N = 30)	36%	82%
	$a_{ph}(443)/a_{ph}(675)$ Total successful classifications: N = 69 (74%)		
	Non-micro-dominated (N = 42)	75%	27%
	Micro-dominated (N = 27)	25%	73%
	$a_{ph}(443)/a_{ph}(555)$ Total successful classifications: N = 65 (70%)		
	Non-micro-dominated (N = 42)	75%	38%
	Micro-dominated (N = 23)	25%	62%

A note on the classification of samples into micro-dominated subclasses: The parameter $a_{ph,n}(443)$ classifies moderately and highly micro-dominated samples successfully with a success rate of at least 80%. The parameters $a_{ph}(443)/a_{ph}(675)$ and $a_{ph}(443)/a_{ph}(555)$ successfully classifies moderately micro-dominated samples with success rates of 68% and 55% respectively, and successfully classifies highly micro-dominated samples with success rates of 80% and 73%, respectively.

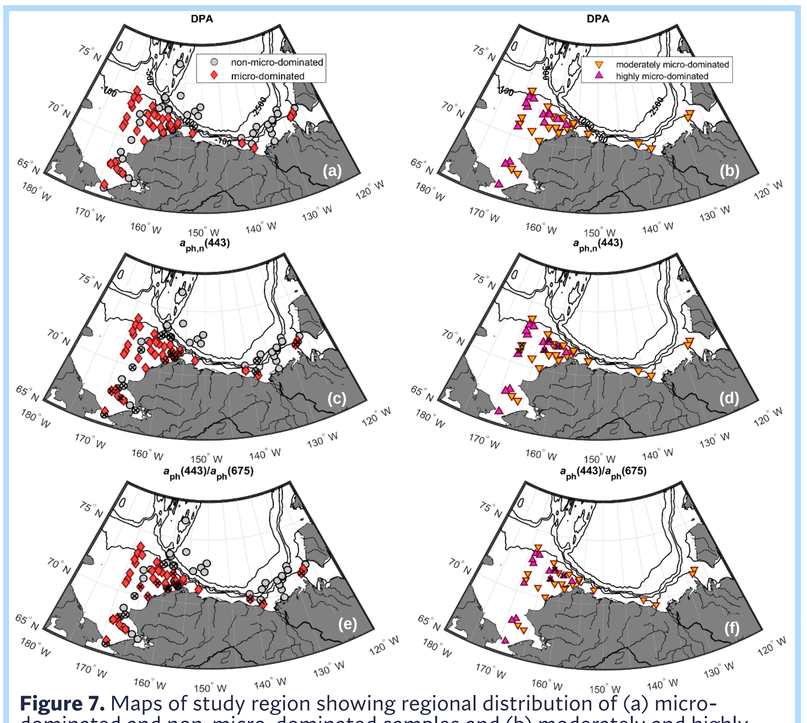


Figure 7. Maps of study region showing regional distribution of (a) micro-dominated and non-micro-dominated samples and (b) moderately and highly micro-dominated samples as obtained from the diagnostic pigment analysis (DPA). In panels (c) and (e), colored points are the same as panel (a) but results of classification into micro- and non-micro-dominated classes using phytoplankton absorption parameters are overlain. Similarly in panels (d) and (f), colored points are the same as panel (b) but results of classification into micro-dominated subclasses using phytoplankton absorption parameters are overlain; points marked "x" represent samples that are misclassified by the absorption parameter denoted in the title of panels (c), (d), (e), and (f).

Conclusions

- Simple a_{ph}-based parameters can distinguish micro- and non-micro-dominated phytoplankton communities, and additionally moderately and highly micro-dominated communities
- Classification schemes presented here can be applied to various datasets including multi- and hyperspectral remotely sensed data
- Can inform us on important environmental regimes in which certain Arctic phytoplankton communities thrive and how they change with changing environmental conditions
- Enables further monitoring of Arctic phytoplankton community composition, especially in the context of the potential shift from micro-dominated to non-micro-dominated communities.

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