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High-resolution monitoring of phytoplankton communities using spectral fluorescence signatures

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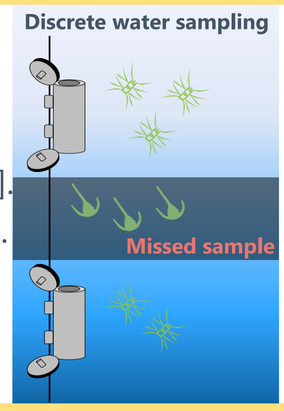
Introduction

- Phytoplankton communities are investigated by analyzing bio-marker pigments (BP) from discrete water samples [1, 2].
- Discrete water samples do not provide high-resolution data.
- Different BP have different fluorescence excitation and emission spectra for specific phytoplankton groups [3].

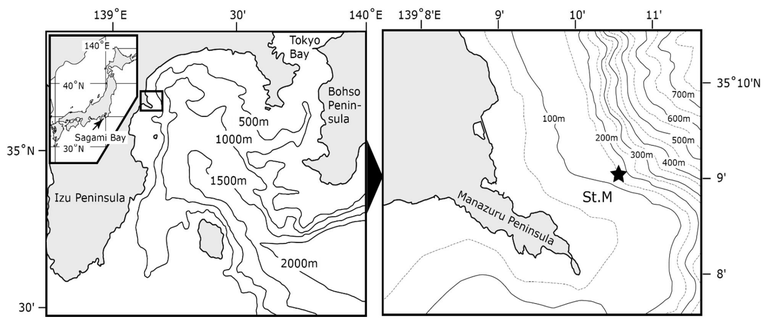


- Spectrofluorometers can predict phytoplankton communities derived from pigment compositions in natural water using a combination of high-resolution data of fluorescence and discrete water samples.

Objective

To clarify the temporal (monthly) variability of the vertical distribution of bio-marker pigments coupled with high-resolution multi-excitation fluorescence.

Materials & Methods



Sampling Location:
Manazuru survey station (St. M) > 2 km away from the Manazuru Peninsula, Kanagawa, Japan

Sampling Period:
Monthly May 2016 to June 2017 (14 months)

Water Sampling:
Optical depths (443 nm) 100, 10, 1, and 0.1%

Measurements:
- Salinity
- Temperature
- Density
- Downwelling irradiance (443 nm)
- Multi-excitation fluorescence [F^{λ}]
- HPLC pigment compositions and concentrations

Peri: Peridinin
Fuco: Fucoxanthin
Buta: 19-butanoyloxyfucoxanthin
Hexa: 19-Hexanoyloxyfucoxanthin
Allo: Alloxanthin
Chl *b*: Chlorophyll *b*
Zeax: Zeaxanthin
Chl *a*: Chlorophyll *a*

Fluorometric-Pigment Model (FPM)

Raw data

Multi-excitation fluorescence [F^{λ}]
- Excitation light 375, 400, 420, 435, 470, 505, 525, 570, 590 [nm]
- Detection 640-1100 [nm]

HPLC pigment composition and concentrations [4]

Calculated values

Fluorometric characterization
- F^{λ}
- Band ratio ($F^{\lambda 1} > F^{\lambda 2}$ [$\lambda 1 > \lambda 2$])

Standardized total 45 variables

Bio-marker pigments (BP) and Chl *a* ratios BP / Chl *a*

Statistical analysis [5, 6]

Principal component scores
- PC1-8 scores

Reduce dimensions by PCA

Sigmoid function fitting

$$f = \frac{1}{1 + \exp[-(c_0 + \sum_{i=1}^{8} c_i S_i)]}$$

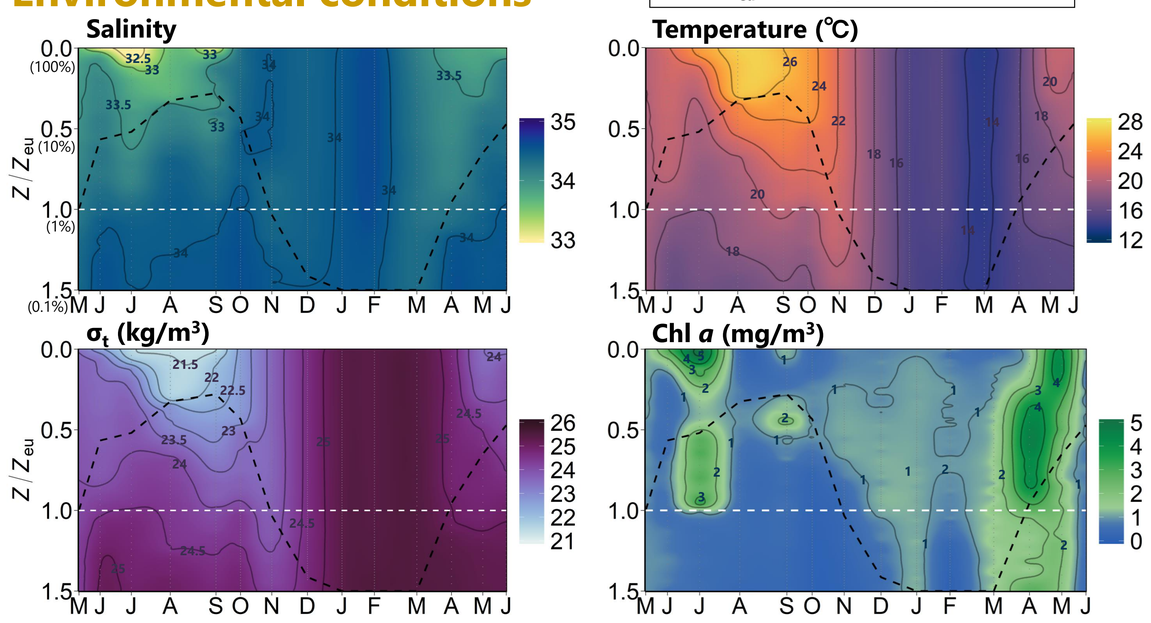
Coefficients: c_0, c_i
PC scores: S_i

BP / Chl *a* ($F_{pigment}$)

Results & Discussion

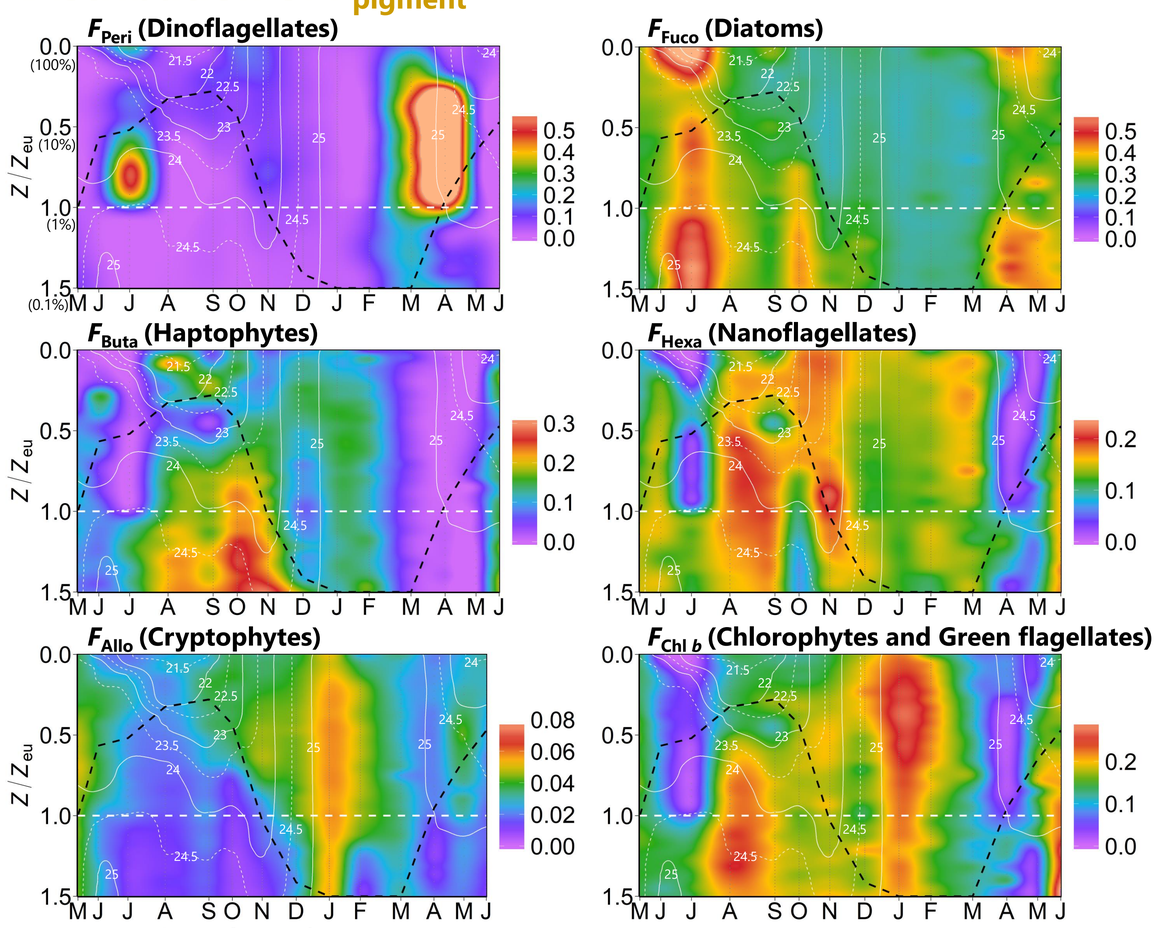
Environmental conditions

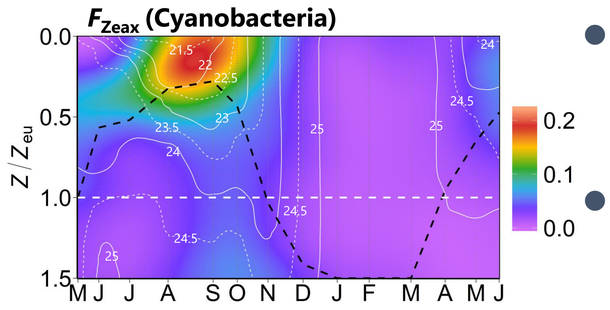
Z / Z_{eu}: Depth / 1% Euphotic Depth
Z_m : Mixed Layer Depth [7]
Z_{eu} : 1% Euphotic Depth



- Physical environmental conditions: **summer stratification** (September, 2016 to October, 2016) and **winter mixing** (December, 2016 to March, 2017)
- Chl *a* derived from relationship between HPLC Chl *a* and F^{470} (log (Chl *a*) = 1.12 * log (F^{470}) + 0.01, r = 0.87, p < 0.01, n = 55)
- High Chl *a* was recorded in July, 2016, April, 2017 and May, 2017. Chl *a* was vertically uniform in distribution from November, 2016 to March, 2017.

Distribution of $F_{pigment}$

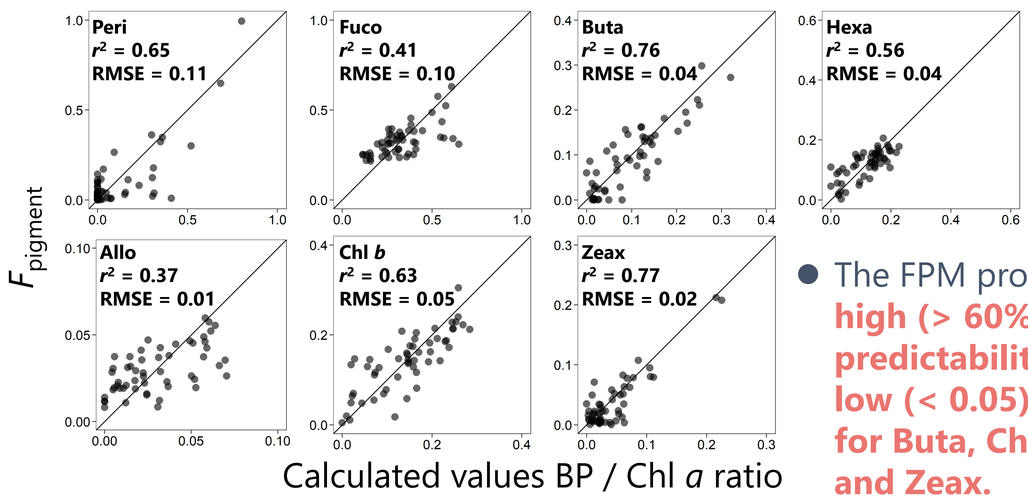




- **High values of the dinoflagellate bio-marker (F_{Peri}) and the diatom bio-marker (F_{Fuco}) were recorded during high Chl *a*.**
- F_{Fuco} peak below the Z_{eu} could be attributed to cell sinking or attachment to sinking aggregates [8].
- **Peak of the cyanobacteria bio-marker (F_{Zeax})was recorded during high temperature and light conditions** (August to September, 2016).
- Nanophytoplankton and picophytoplankton bio-marker (F_{Hexa}, F_{allo}, and $F_{Chl\ b}$) increased during fall and winter (October, 2016 to February, 2017) when microphytoplankton bio-marker (F_{Peri} and F_{Fuco}) were low and during low Chl *a*.

Performances of FPM

r^2: Coefficient of determination
RMSE: Root Mean Squared Error



- The FPM provided **high (> 60%) predictability and low (< 0.05) RMSE for Buta, Chl *b*, and Zeax.**
- Low performance of FPM of Fuco and Allo is due to the lack of fluorescence data when Fuco and Allo concentration are low and high, respectively.
- Low performance of FPM of Peri is due to high RMSE (0.11) at low concentrations.

Conclusion

- Although the FPM of Peri, Fuco and Allo did not provide sufficient quantitative values, **the method was useful in elucidating the temporal and vertical distribution of phytoplankton groups, particularly cyanobacteria, haptophytes and chlorophytes in the region**.

References

[1] Claustre, 1994; [2] Mackey et al., 1996; [3] Bricaud et al., 2004; [4] Head and Horne, 1993;
[5] Wang et al., 2016; [6] Fujiwara et al., OOXXIII poster; [7] Weller and Plueddemann, 1996; [8] Kheireddine et al., 2017

Acknowledgments

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