The annual cycle of phytoplankton pigment composition, optical properties and photosynthetic quantum efficiency (PQE) in the western English Channel

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Main objective:

To monitor the variation and co-variation of pigments, carbon, phytoplankton absorption and photosynthetic quantum efficiency (PQE) over a seasonal cycle.

Prior knowledge driving the study:

- Preferential Chla synthesis in healthy algae and vice versa.

- Ratio of optical absorption of phytoplankton extracts at different wavelengths reflects pigment concentrations and the "health" of cells:
  - 430/665nm (Tpig/Chla) – increased at low nutrients - Margalef, 1967
  - 480/665nm (red to blue, Car.:Chla) – increased as cells aged -Jeffrey & Hallegraeff, 1980 and Heath et al., 1990.
- Co-variance of a480/a665 and Cph/Chla – low in "healthy cells" – Heath et al., 1990.

- This study: a674/a443 and a674/a490
- Link to an indicator of photosynthetic quantum efficiency.

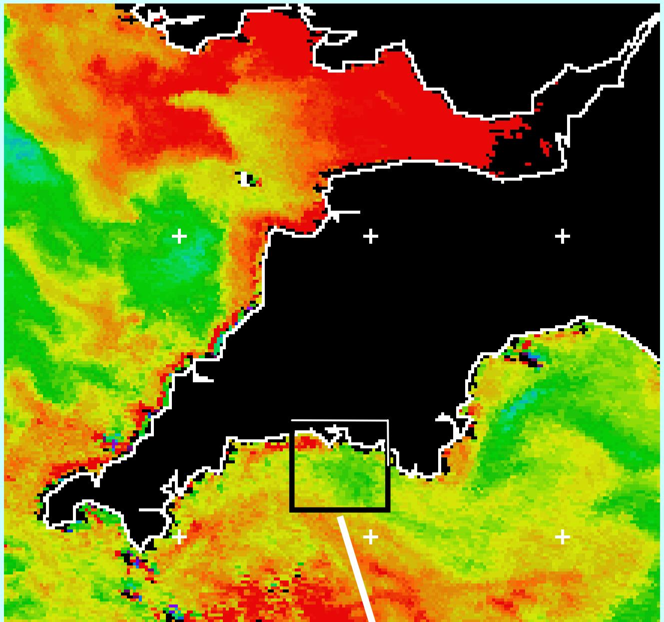
Overview of presentation

- Introduce the study site
- Methods and materials
- Overview of seasonal variation at the site
- Relationships between:
    - PAR and other parameters
    - PQE, pigments and pigment ratios
    - Absorption ratios, pigments and PQEm
    - Phytoplankton carbon pigments and PQEm
- Summary

Reference for this work:

Jim Aiken, James Fishwick, Gerald Moore and Katharine Pemberton (2004) The annual cycle of phytoplankton photosynthetic quantum efficiency, pigment composition and optical properties in the western English Channel. *J. Mar. Biol. Ass, U.K*. **84**: 1-13.

Station ‘L4’

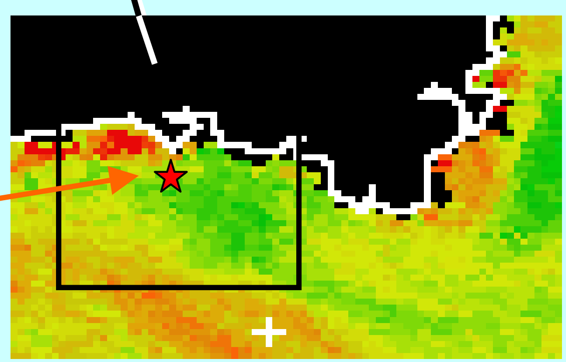


- Weekly sampling in 2001 (n = 44)
- 10 km off the coast of Plymouth in the Western English Channel
- 51m depth
- Seasonally stratified
- Succession of blooms from Mar to Sep

L4

(50º15’N,

4º13’W)



Methods 1. Parameters measured:

- Photosynthetic quantum efficiency (PQE) – FRRF
- CTD measurements
- Optical profilers in 7 wavebands
- HPLC analysis for pigments (surface)
- Nutrient analysis (surface)
- Phytoplankton particle absorption spectra (surface)
- Phytoplankton species counts – converted to carbon using formulae of Strathmann (1967). (surface)

Methods 2. Calculation of phytoplankton photosynthetic quantum efficiency (PQE)

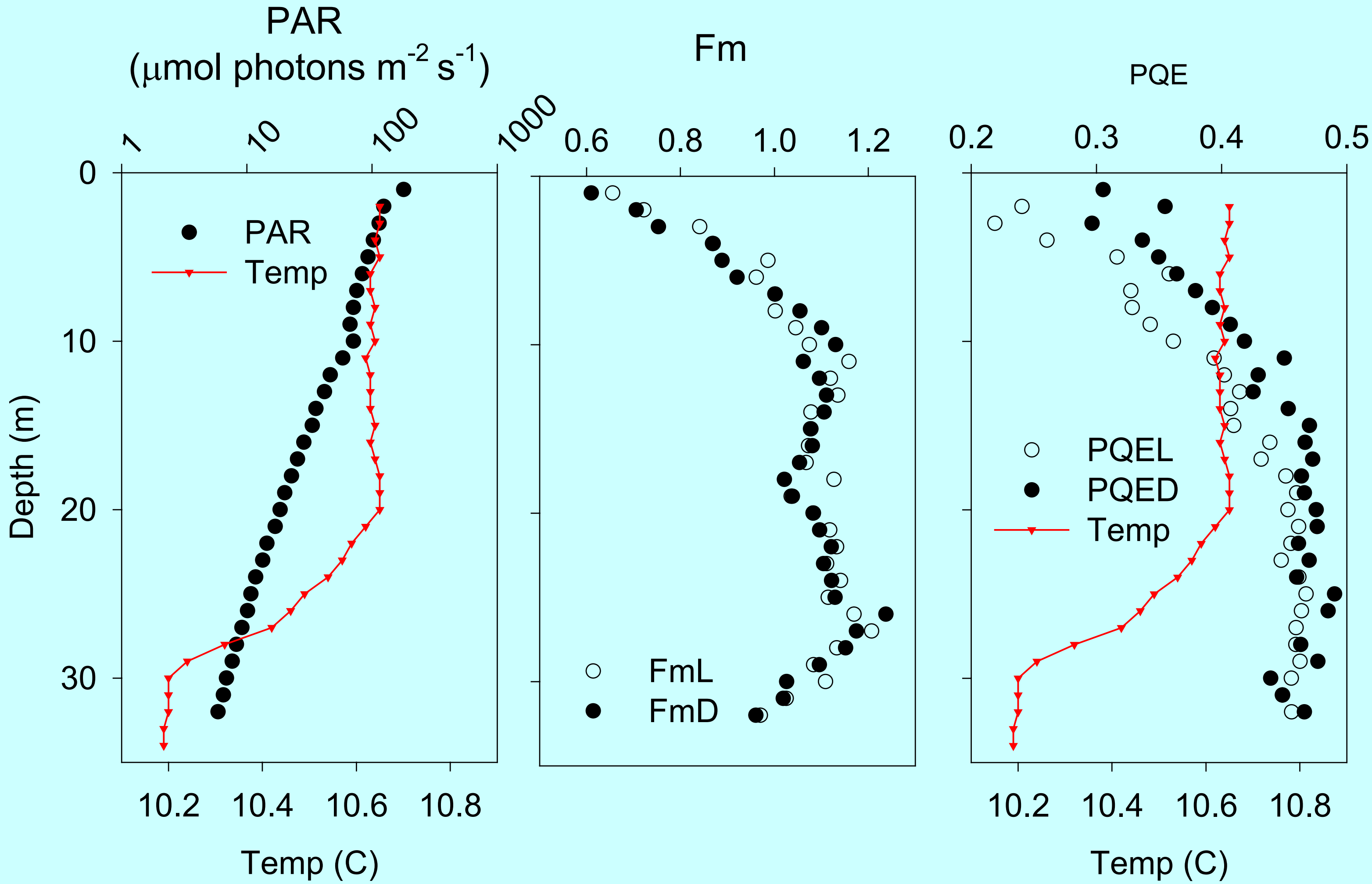
$$PQE' = Fv' / Fm'$$

$$\text{where } Fv' = Fm' - F0'$$

- Reflects the efficiency of photosystem II in the light adapted state.
- FRRF Dark chamber 0.2 to 1.0s flushing time allow relaxation of photochemical but not non-photochemical quenching.

Methods 3. Derivation of daily values of PQEm

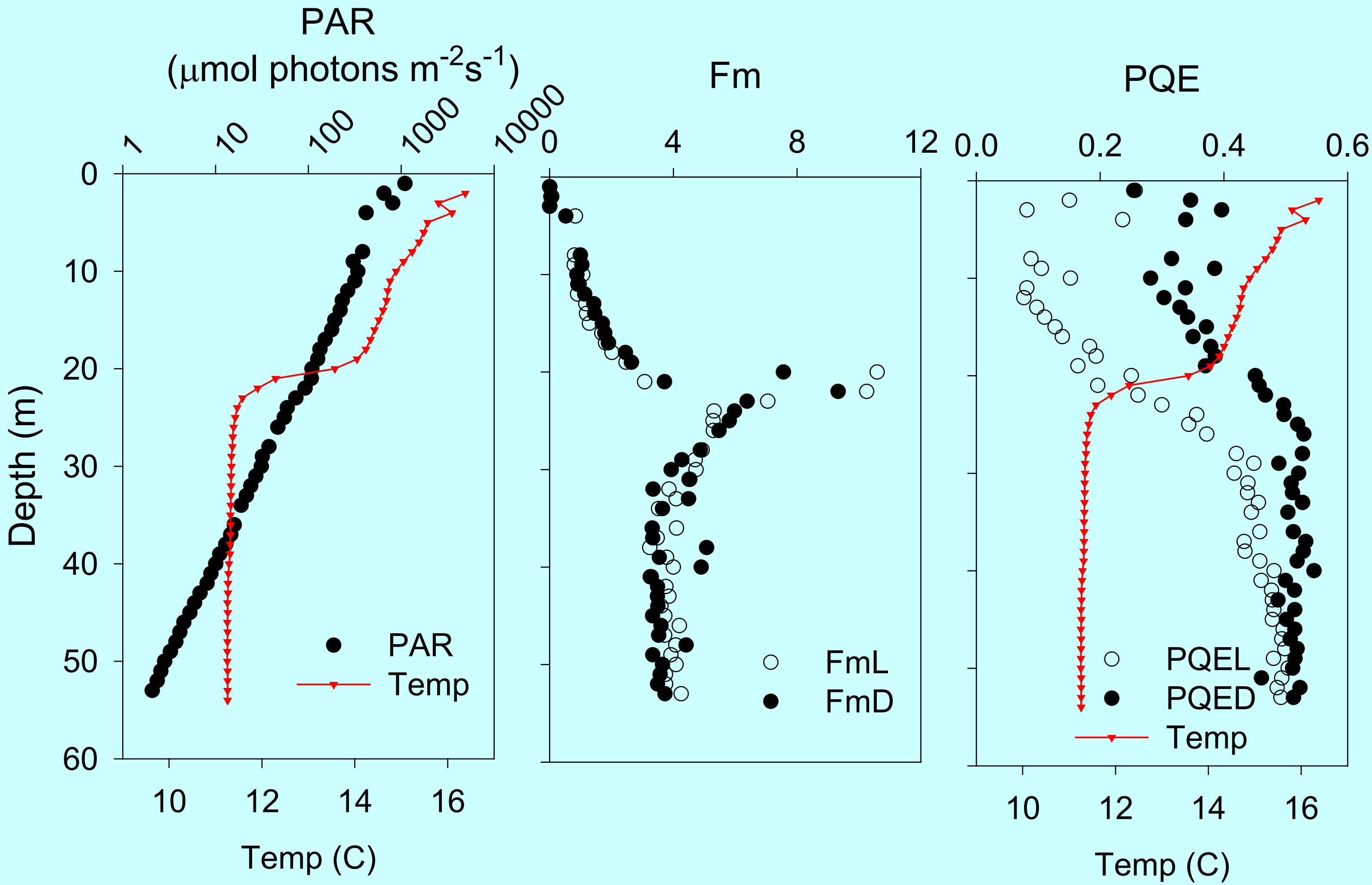
a) Typical FRRF profiles during "non-stratified" part of year



•PQE used was subsurface value where constant value had been obtained and L and D chamber values converged.

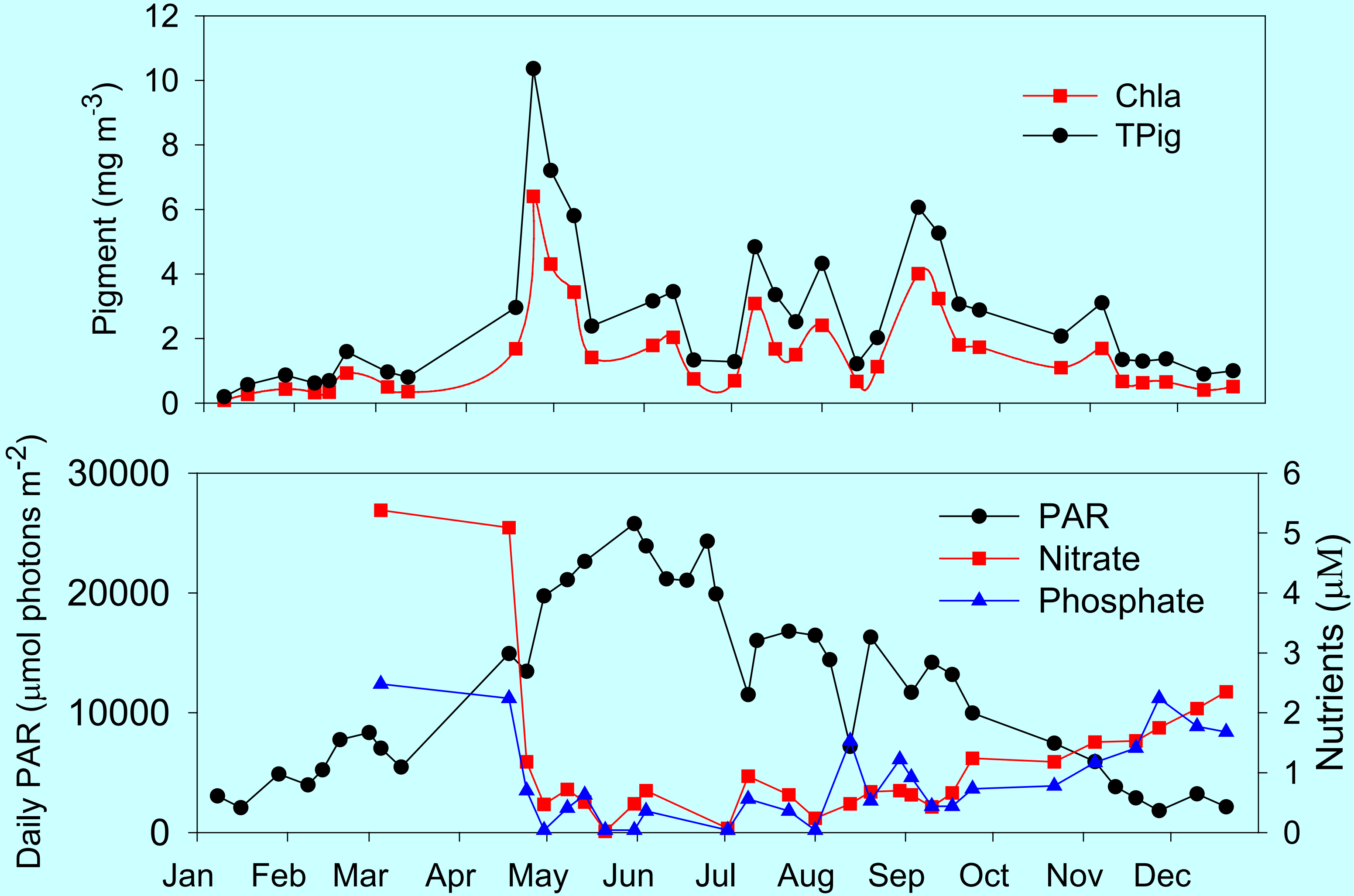
Methods 3b. Derivation of daily values of PQEm

b) Typical FRRF profiles during summer stratification



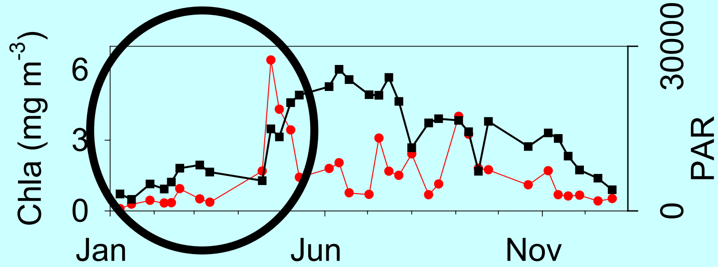
- PQE derived for both surface and thermocline layer where possible.
- Not possible when quenching extended below surface layer.

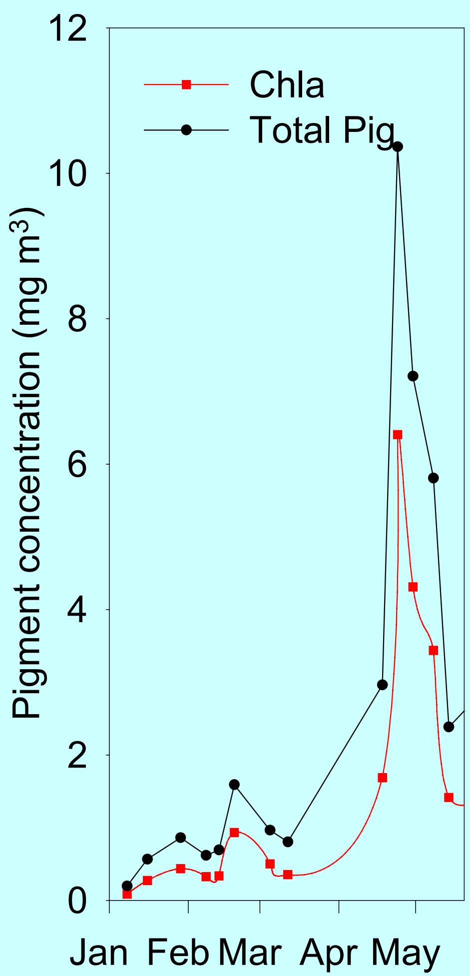
Seasonal variation of parameters: Overview

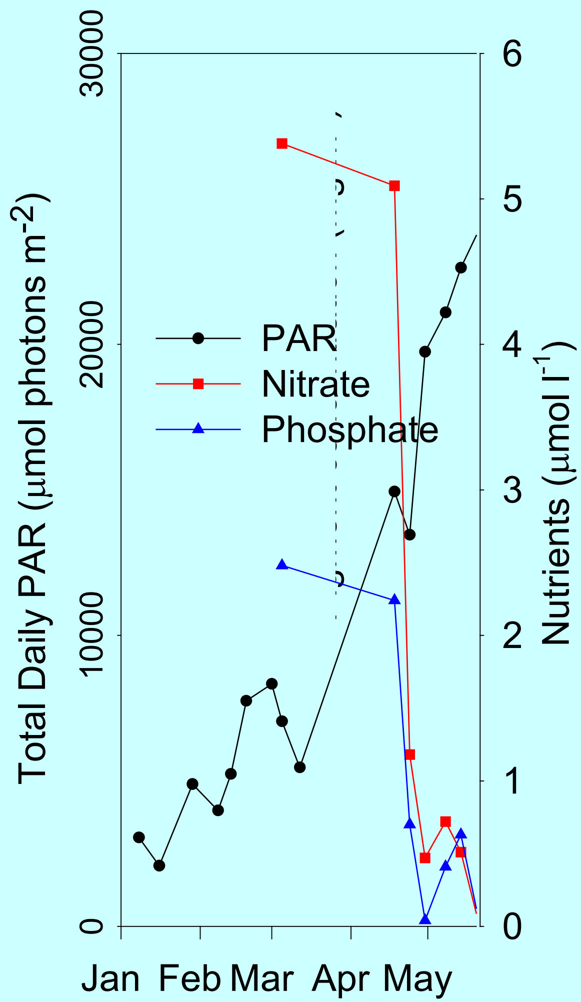


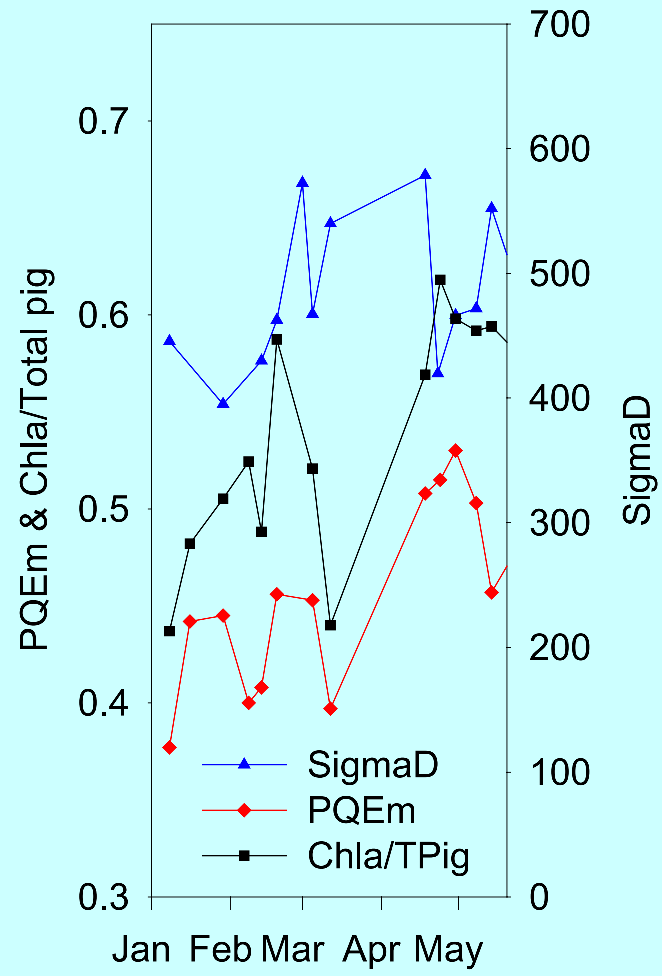
Seasonal variation of parameters:

Mid Winter to Spring Bloom (MWSB)

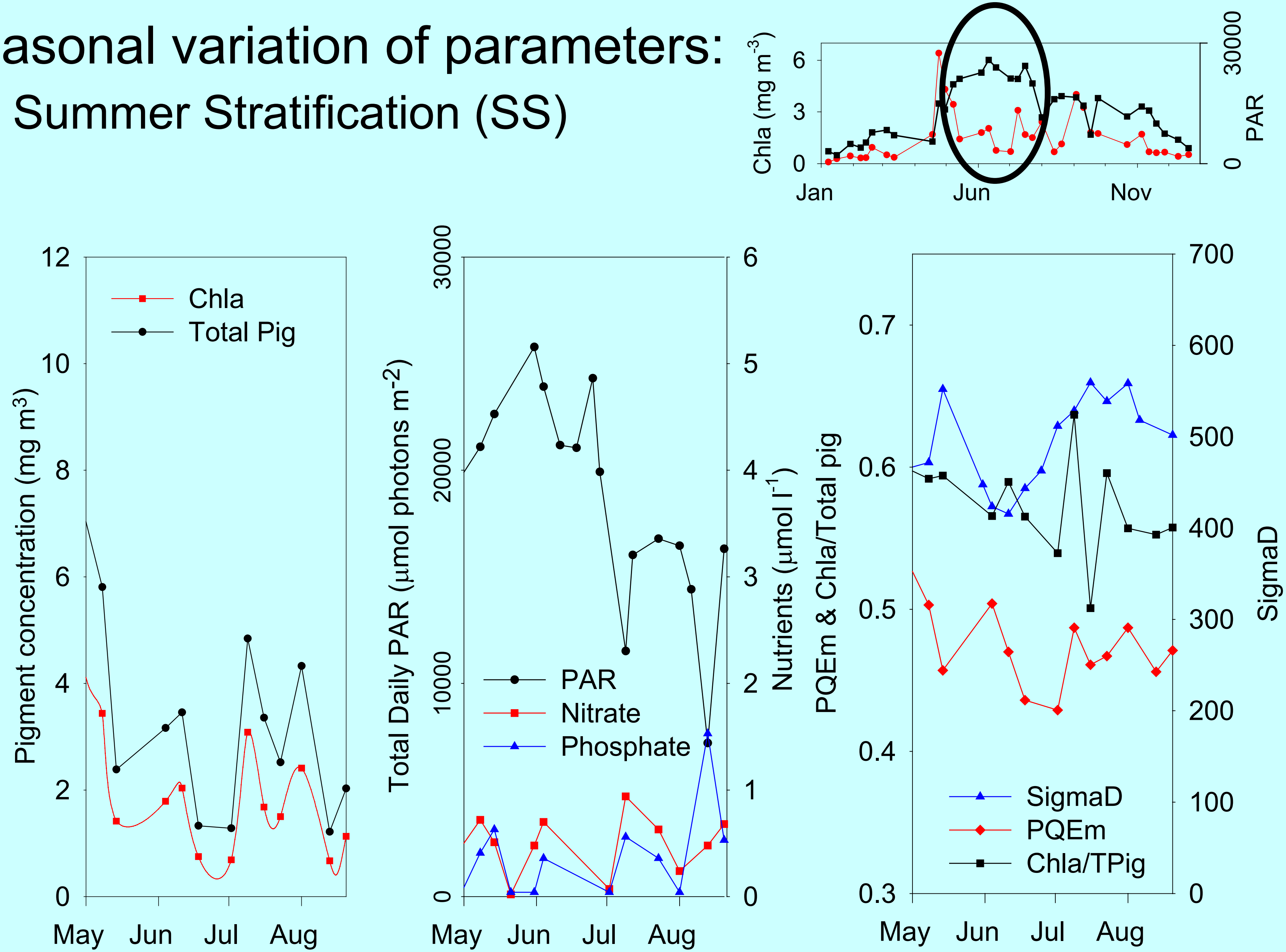






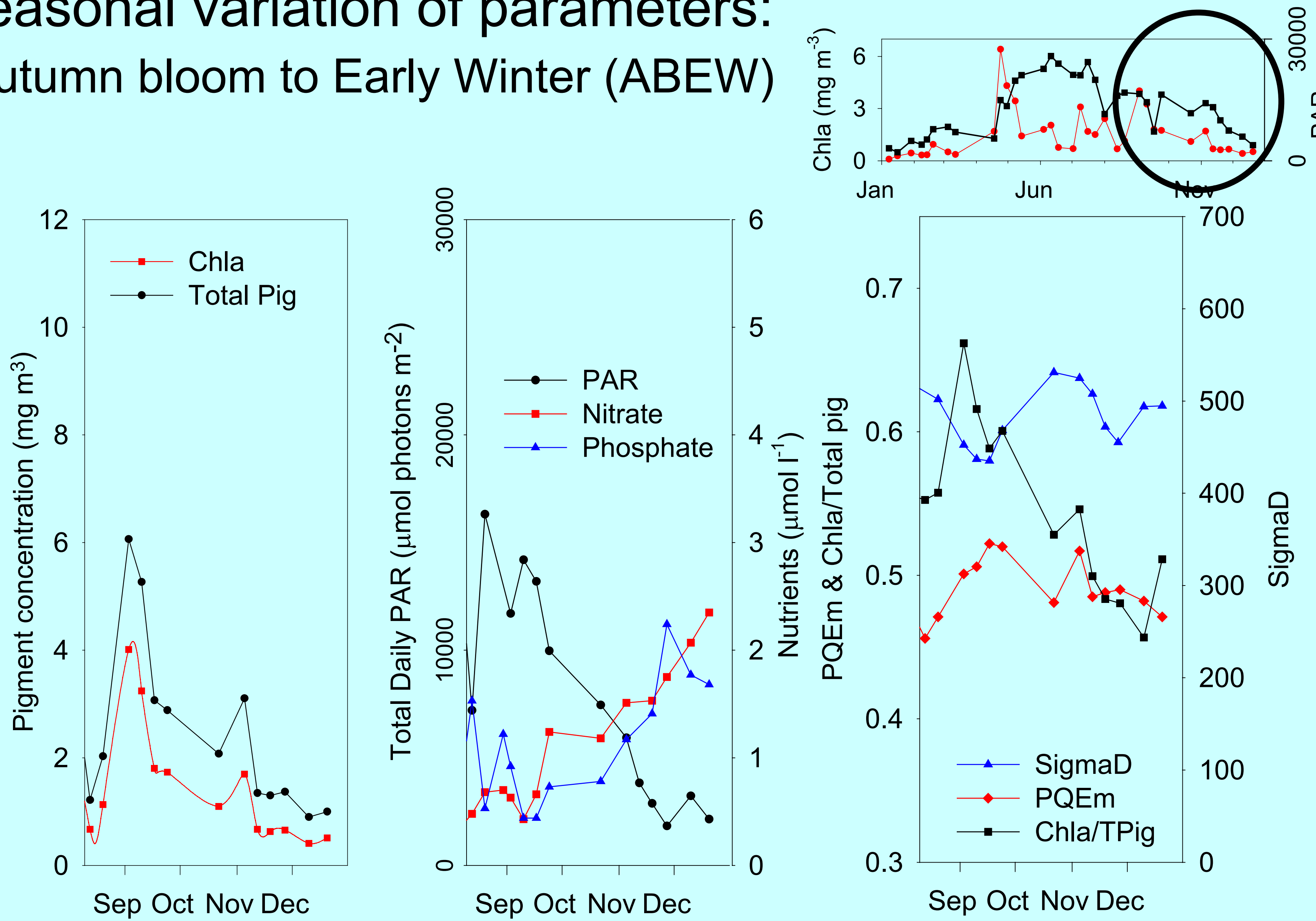


Seasonal variation of parameters:
Summer Stratification (SS)

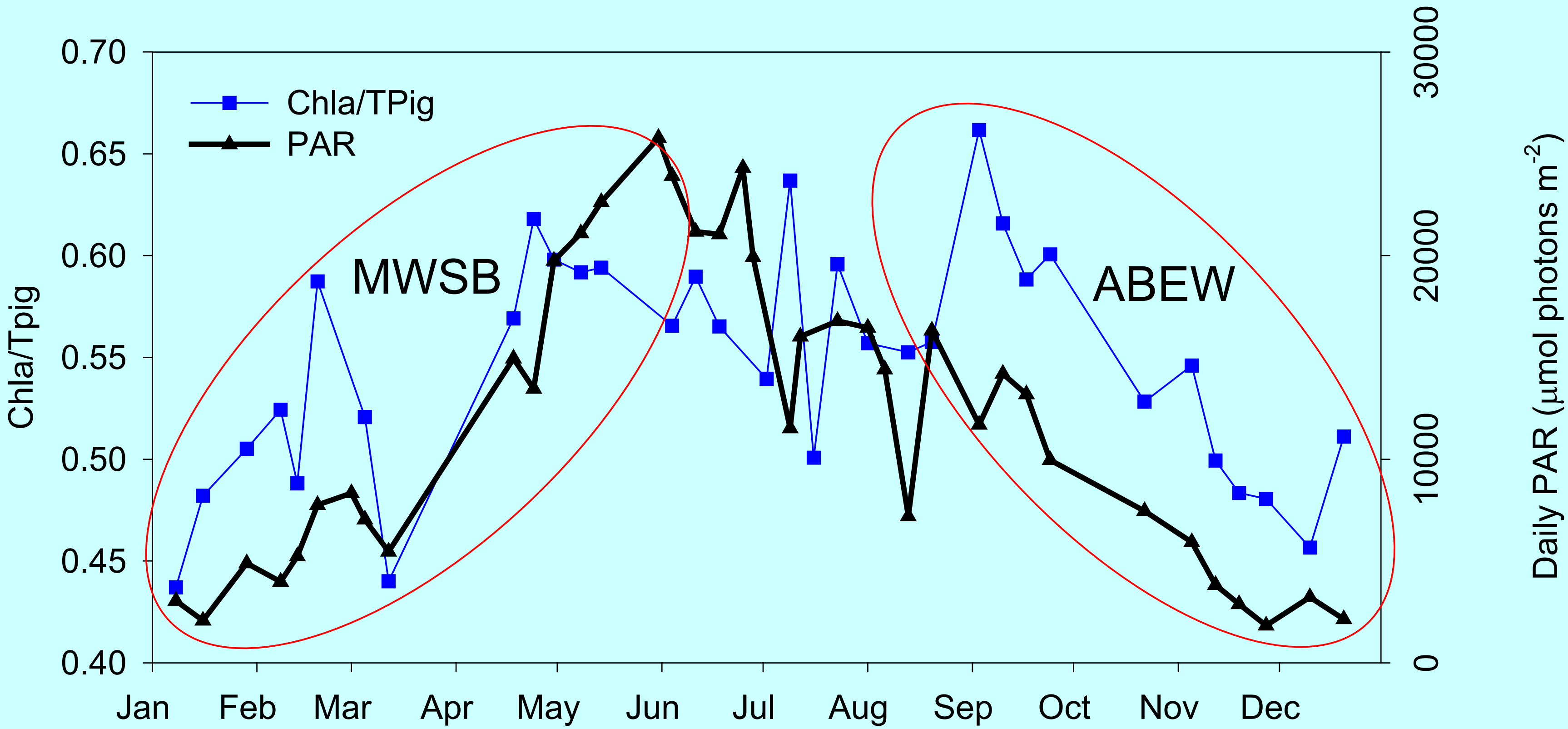


Seasonal variation of parameters:

Autumn bloom to Early Winter (ABEW)

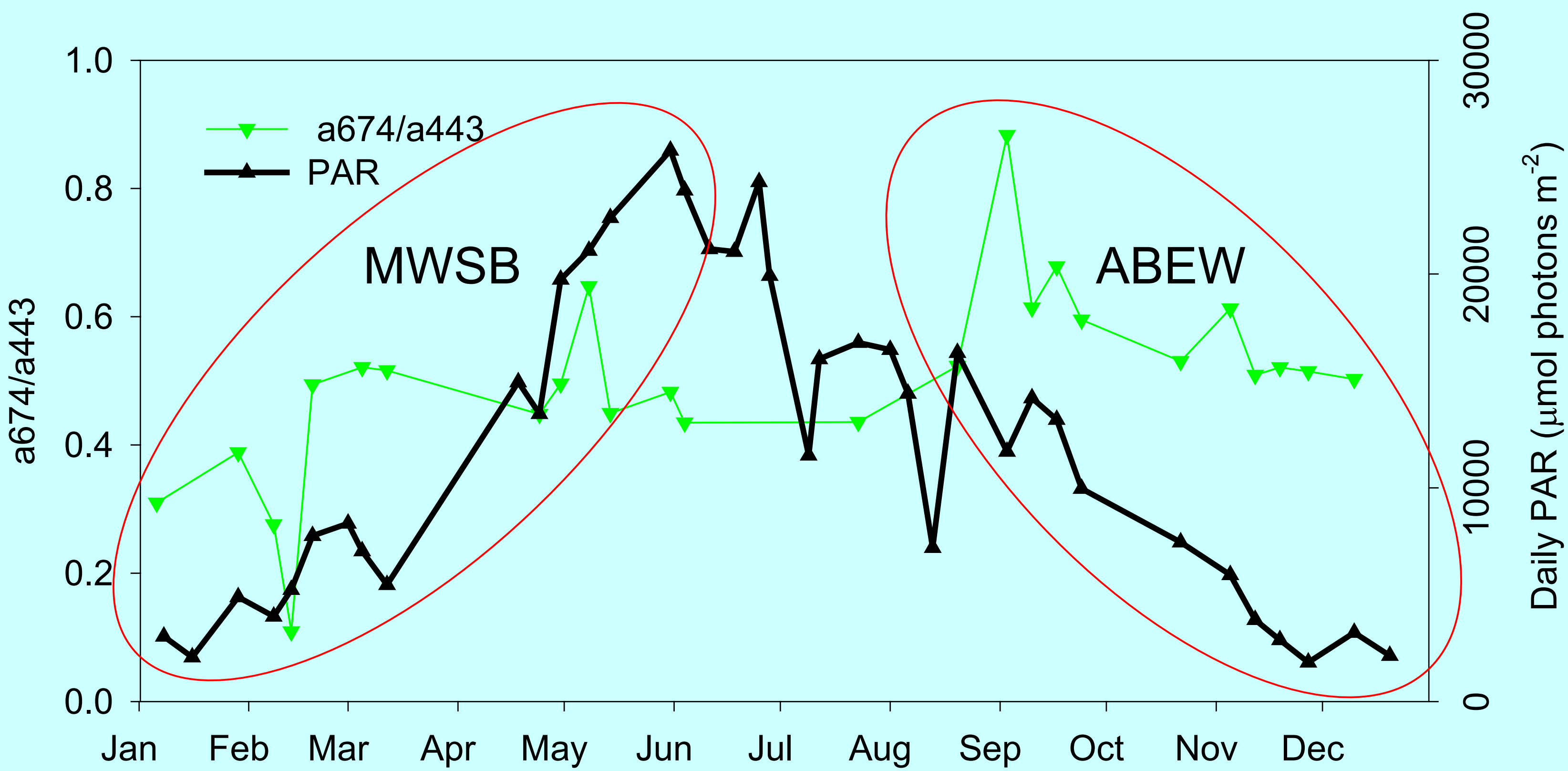


Relationship with PAR – Chla/Tpig



Significant relationship between
- 4 day PAR and Chla/Tpig for MWSB ($R^2 = 0.96$)
- 1 day PAR and Chla/Tpig for ABEW ($R^2 = 0.83$)

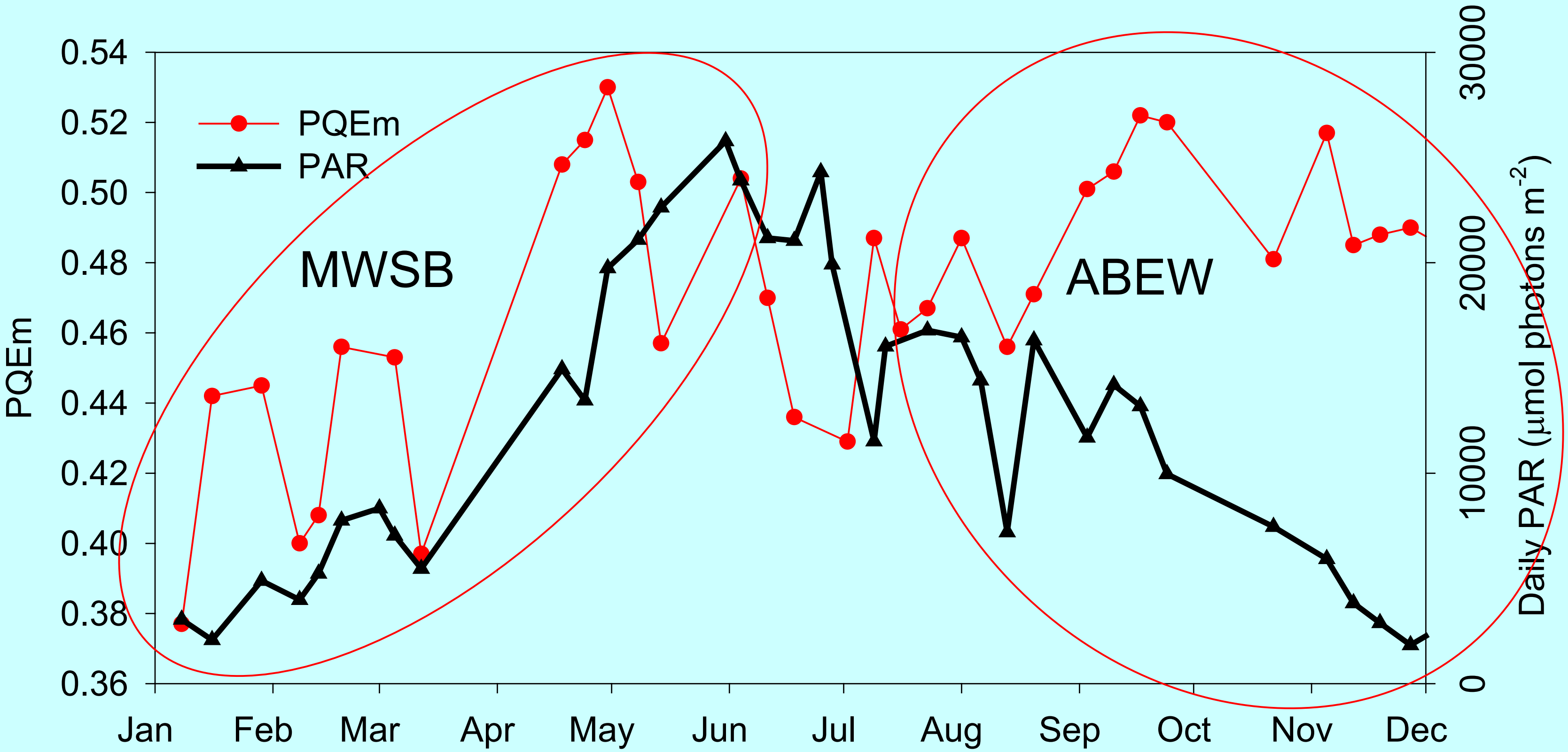
Relationship with PAR – a674/a443



Significant relationship between

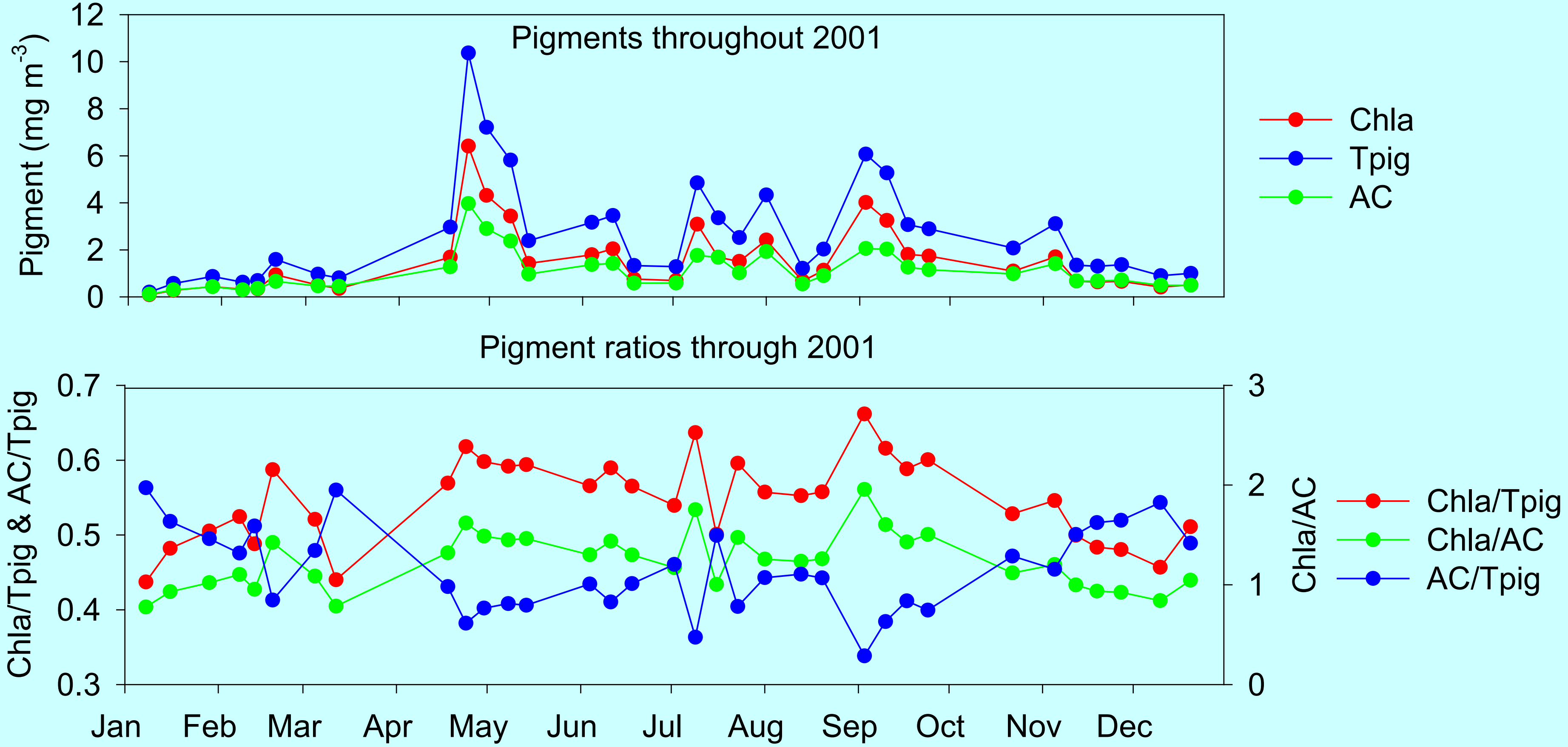
- 4 day PAR and a674/a443 for MWSB ($R^2 = 0.76$)
- 4 day PAR and a674/a443 for ABEW ($R^2 = 0.80$)

Relationship with PAR – PQEm

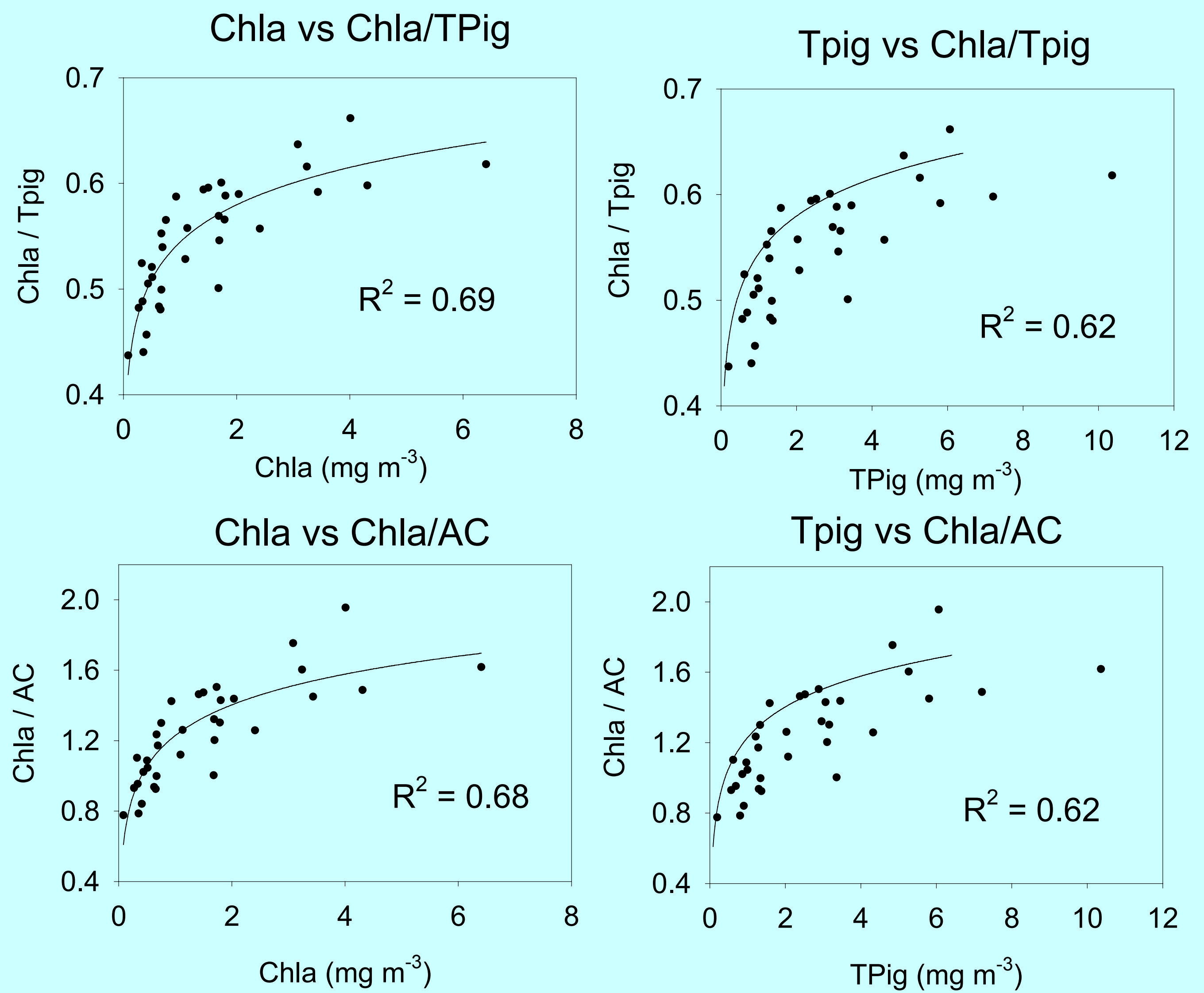


Significant relationship between
- 1 day PAR and PQEm for MWSB (R^2 = 0.90)
- 1 day PAR and PQEm for ABEW (R^2 = 0.71)

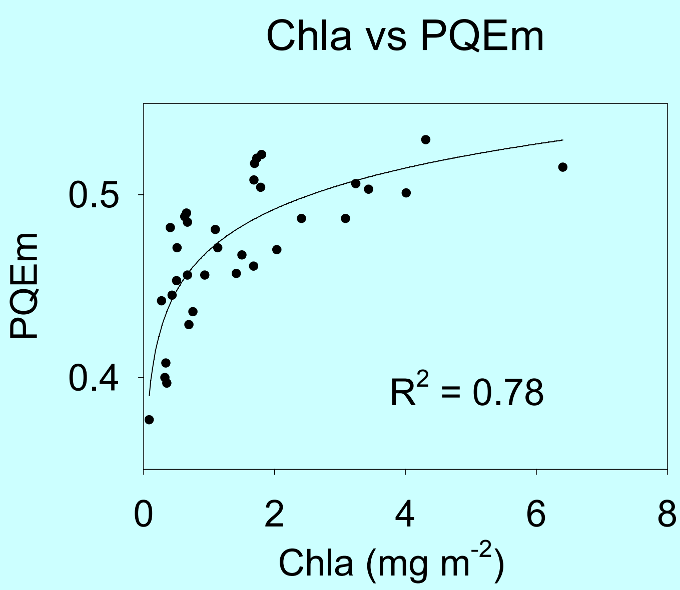
Relationship between pigments and pigment ratios

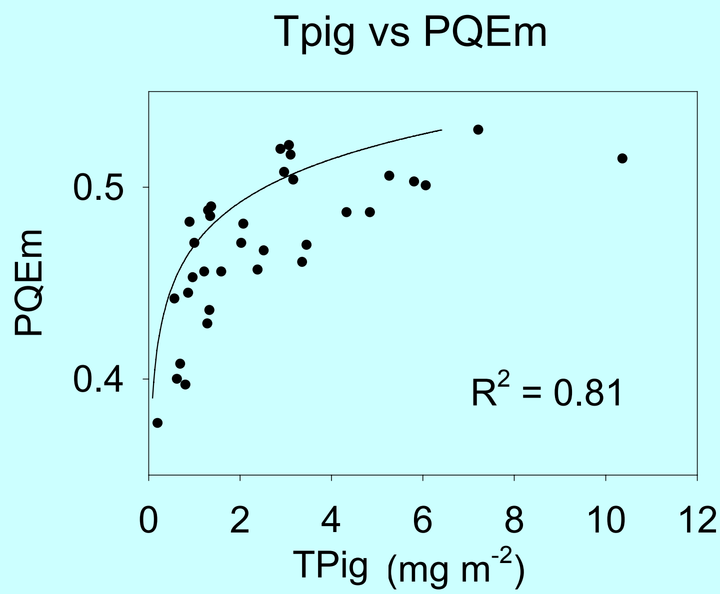


Relationship between pigments and pigment ratios

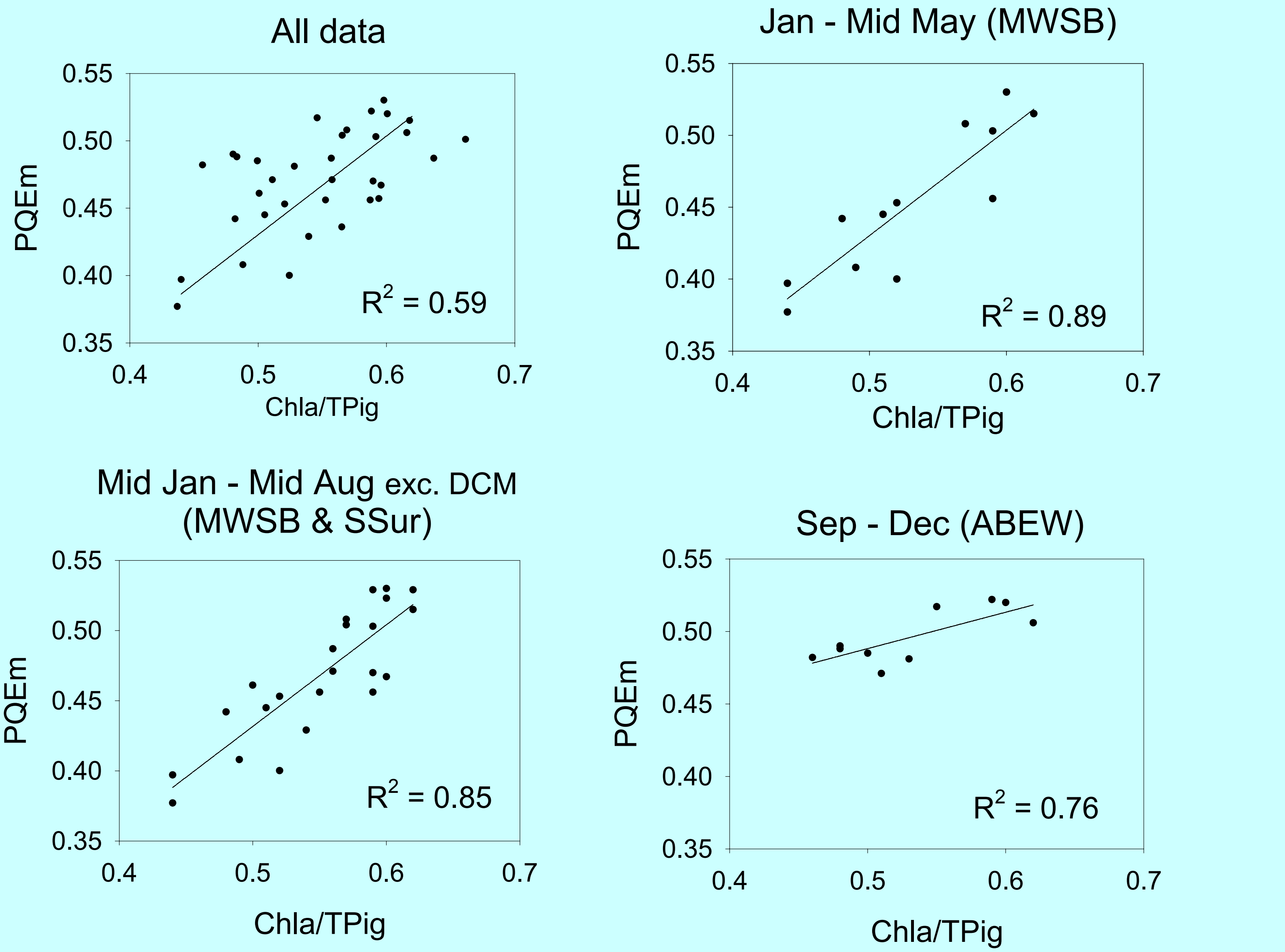


Relationship between PQEm and Chla or TPig





Relationship between PQEm and Pigment ratios

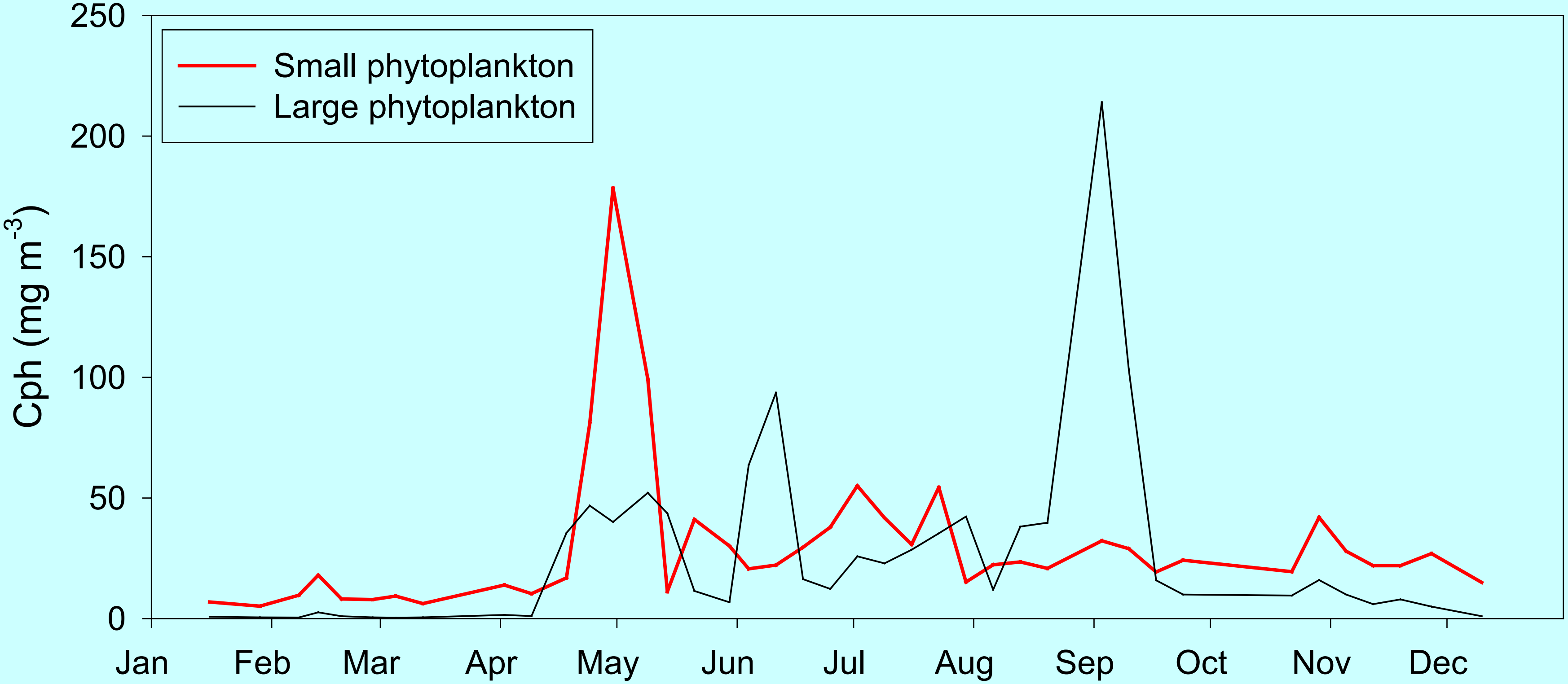


Relationship between absorption ratios and other parameters

- Absorption ratios showed similar patterns to cycles of Chla/Tpig and PQEm
- Fewer data and low signal to noise
- Ratios low in winter, peaked in spring bloom, fluctuated through summer, peaked again in autumn and declined in winter

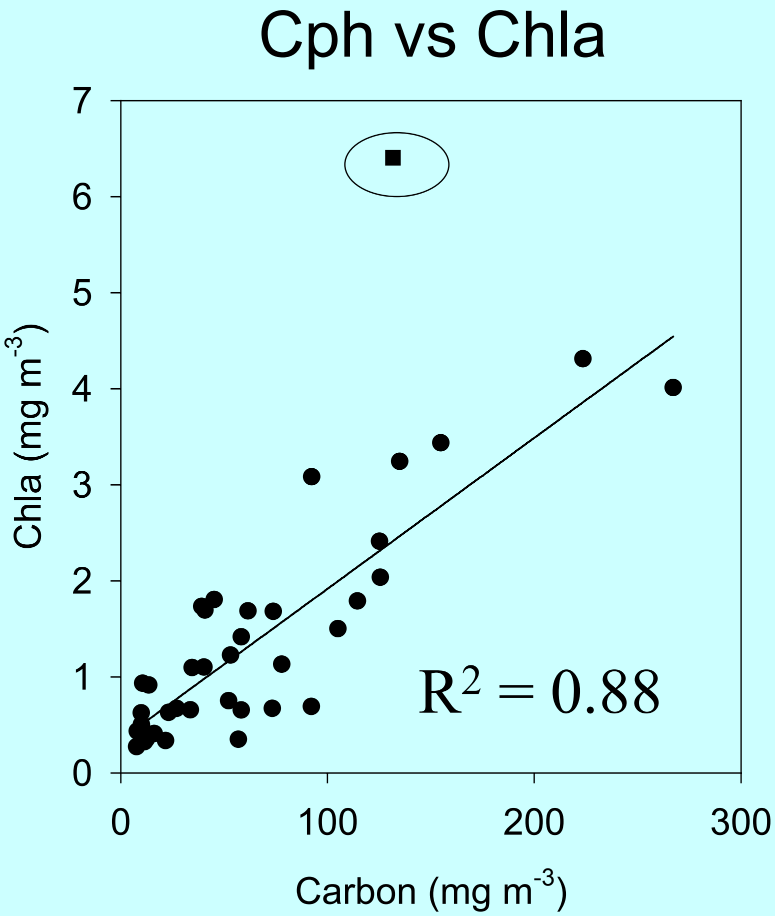
Independent variable	Dependent variable	Type relationship	Slope	Intercept	R	N
Chla	a674/a443	Log	0.115	0.499	0.66	25
Tpig	a674/a443	Log	0.130	0.419	0.67	25
PQEm	a674/a443	Linear	2.347	-0.613	0.63	25
Chla/Tpig	a674/a443	Linear	1.322	-0.223	0.52	25
PQEm	a674/a443	Linear	2.819	-0.596	0.65	25
Chla/AC	a674/a443	Linear	0.293	0.379	0.49	25

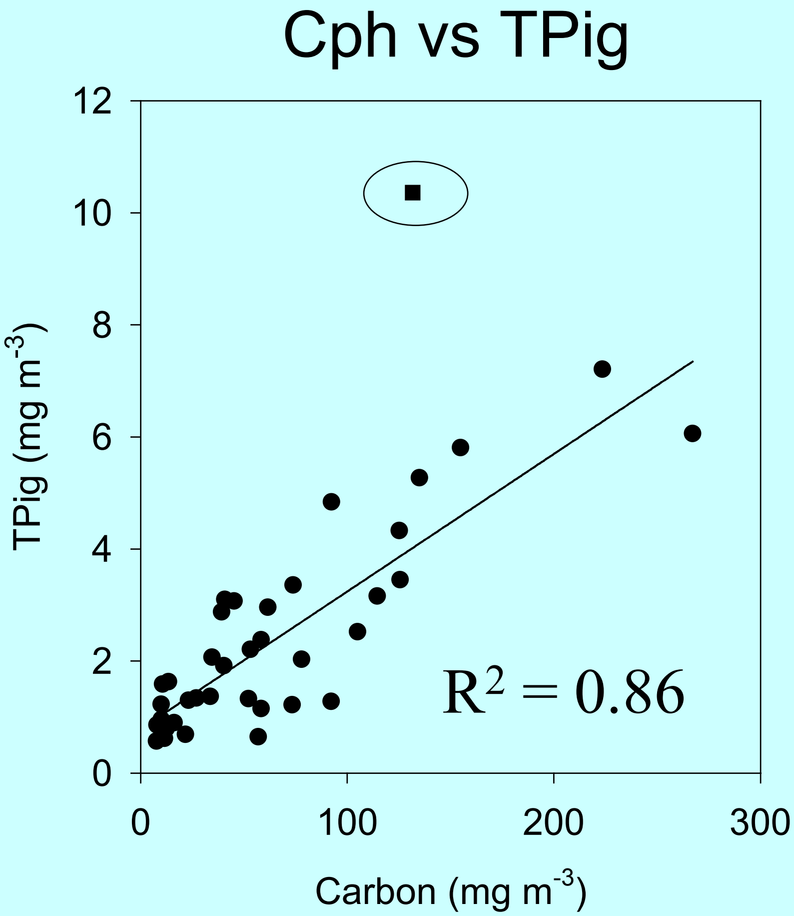
Relationship between phytoplankton carbon (Cph) and other parameters



- Similar pattern to pigments: low in winter, peak in spring, summer and autumn blooms and declining from autumn to winter
- Original phytoplankton data condensed into 2 groups:
  - small (picoplaknton and flagellates) and
  - large (coccolithophores, dinoflagellates, diatoms and other).

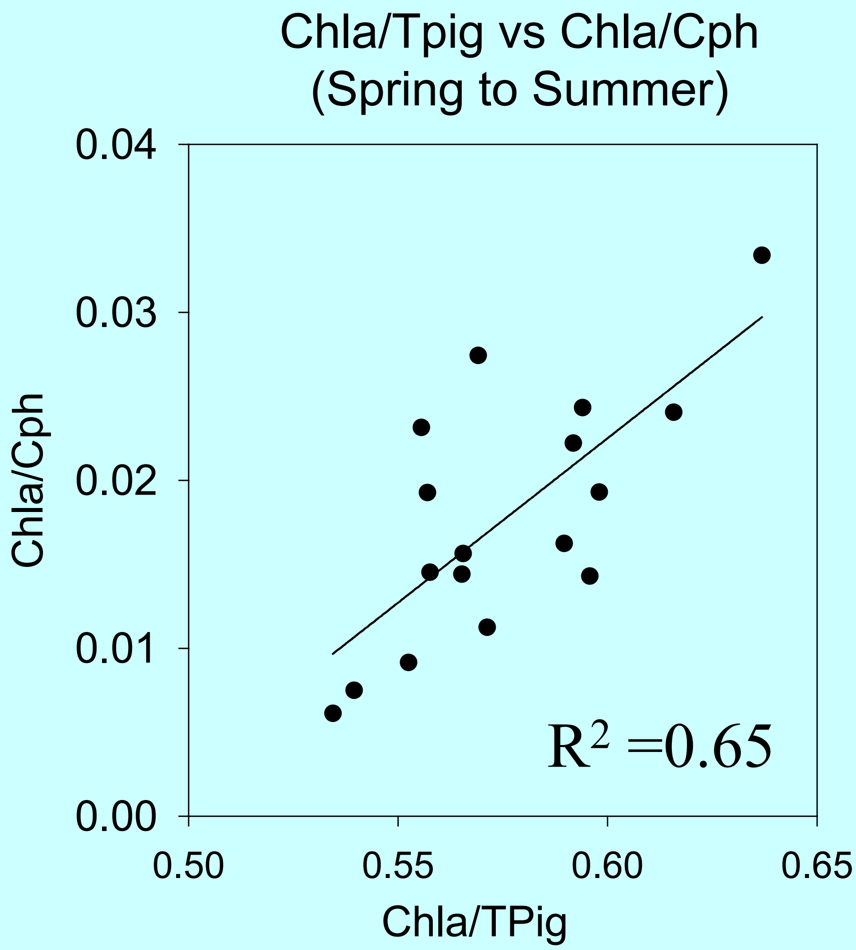
Relationship between carbon and other parameters:

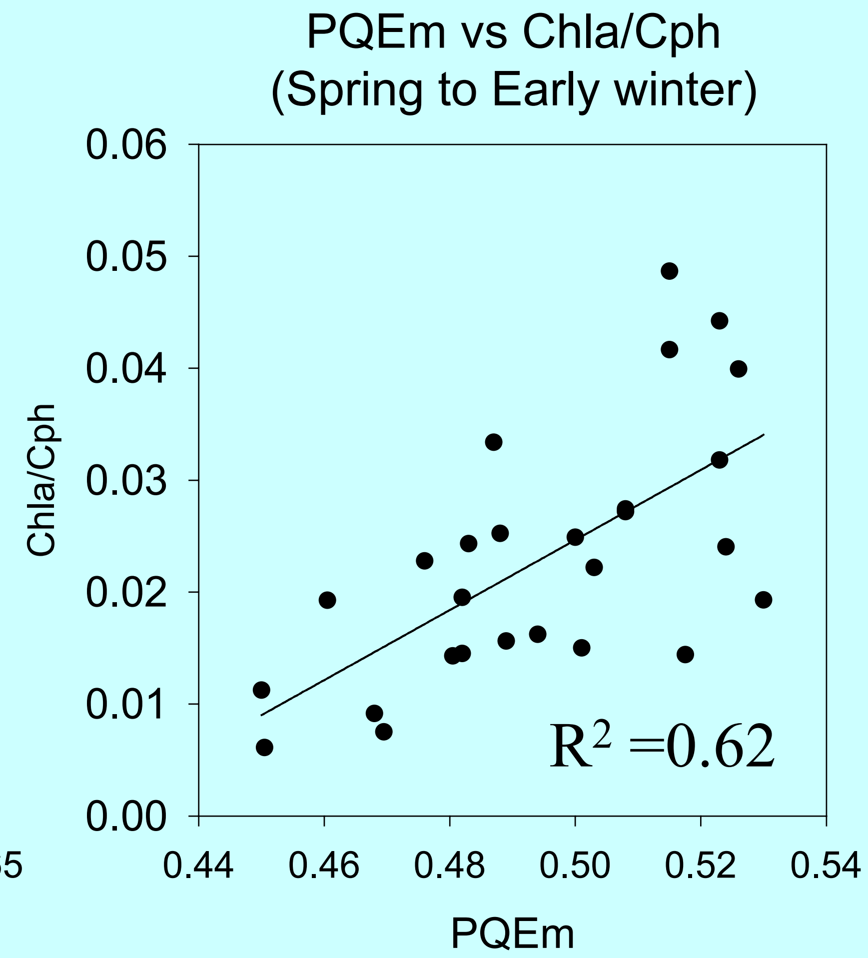




- Chla and Tpig significantly correlated to carbon
- Outliers occurred when high proportion of flagellates

Relationship between carbon and other parameters:





- Chla/C and Tpig/C significantly correlated to PQEm outside of periods with high flagellates in the population.

Summary

Chla and Tpig

- closely correlated for whole year
- correlated to Cph

Chla/TPig

- low in winter and higher during blooms
- correlated to recent light fluxes, PQEm, optical absorption ratios and for most of year to Chla/Cph

Optical absorption ratios

- correlated with Chla/Tpig and PQEm

Final notes...

- PQEm, Chla/Tpig, Chla/Cph and a674/a443 are greater when plants are growing actively
- When nutrients sufficient, PQEm, Chla/Tpig and a674/a443 are linear functions of light

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