Phytoplankton physiology in the Ross Sea

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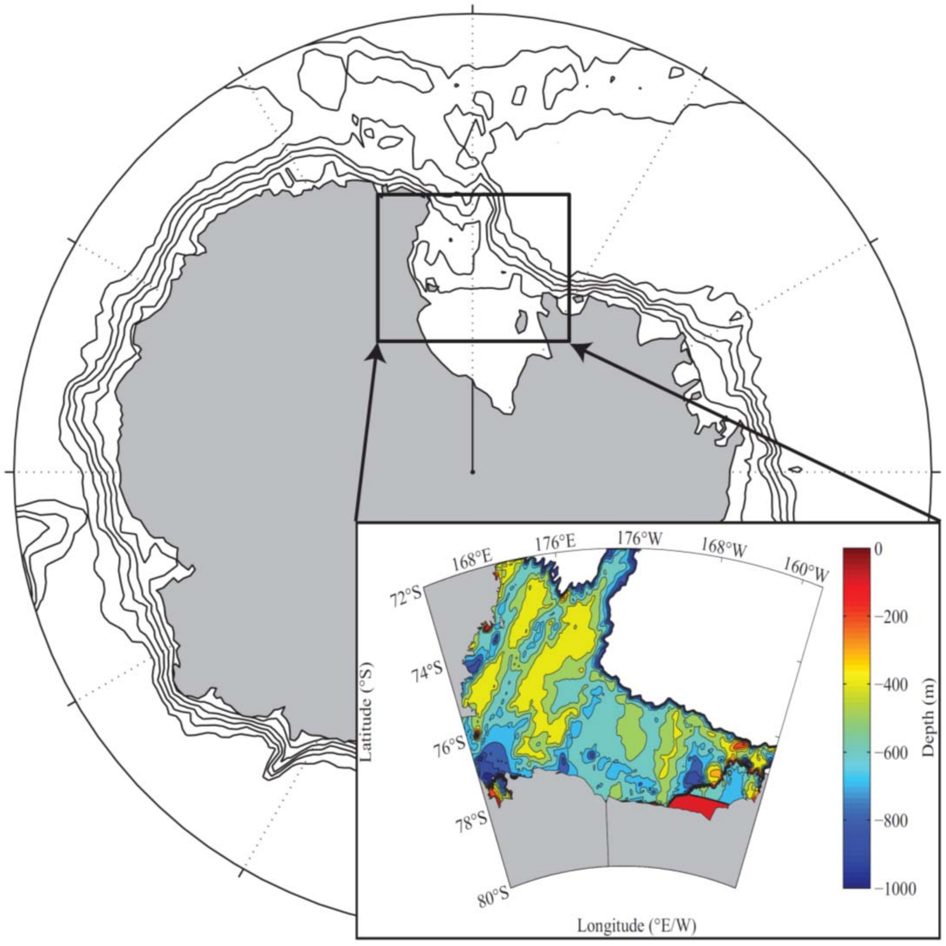
Objectives:

- To map the spatial/temporal extent of iron limitation 'physiologically' throughout the Ross Sea

- To gain an understanding of the molecular-level responses of phytoplankton to low iron concentrations in the Ross Sea



Background: Options for Photoacclimation

The Photosynthetic Unit (PSU)

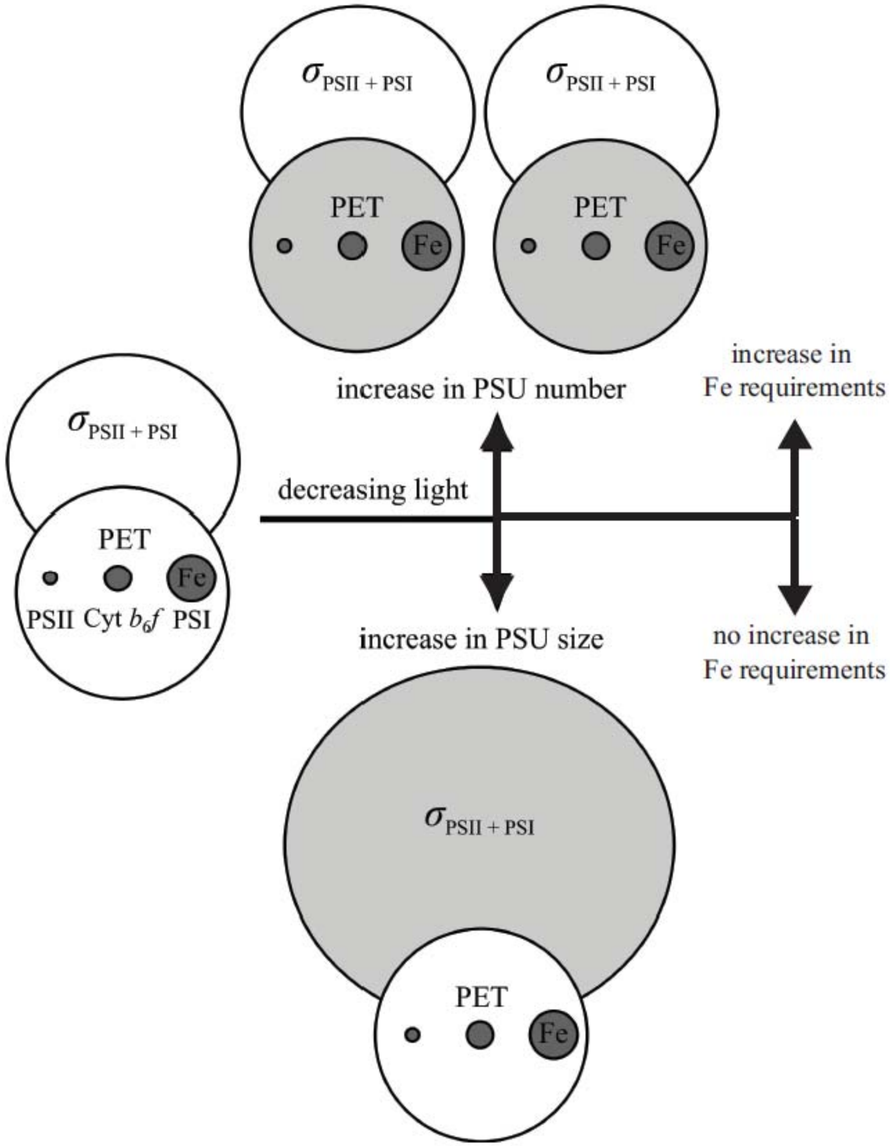
N-type – Number of photosynthetic units

Low Chl:Fe (higher iron demand)
Higher catalytic capacity

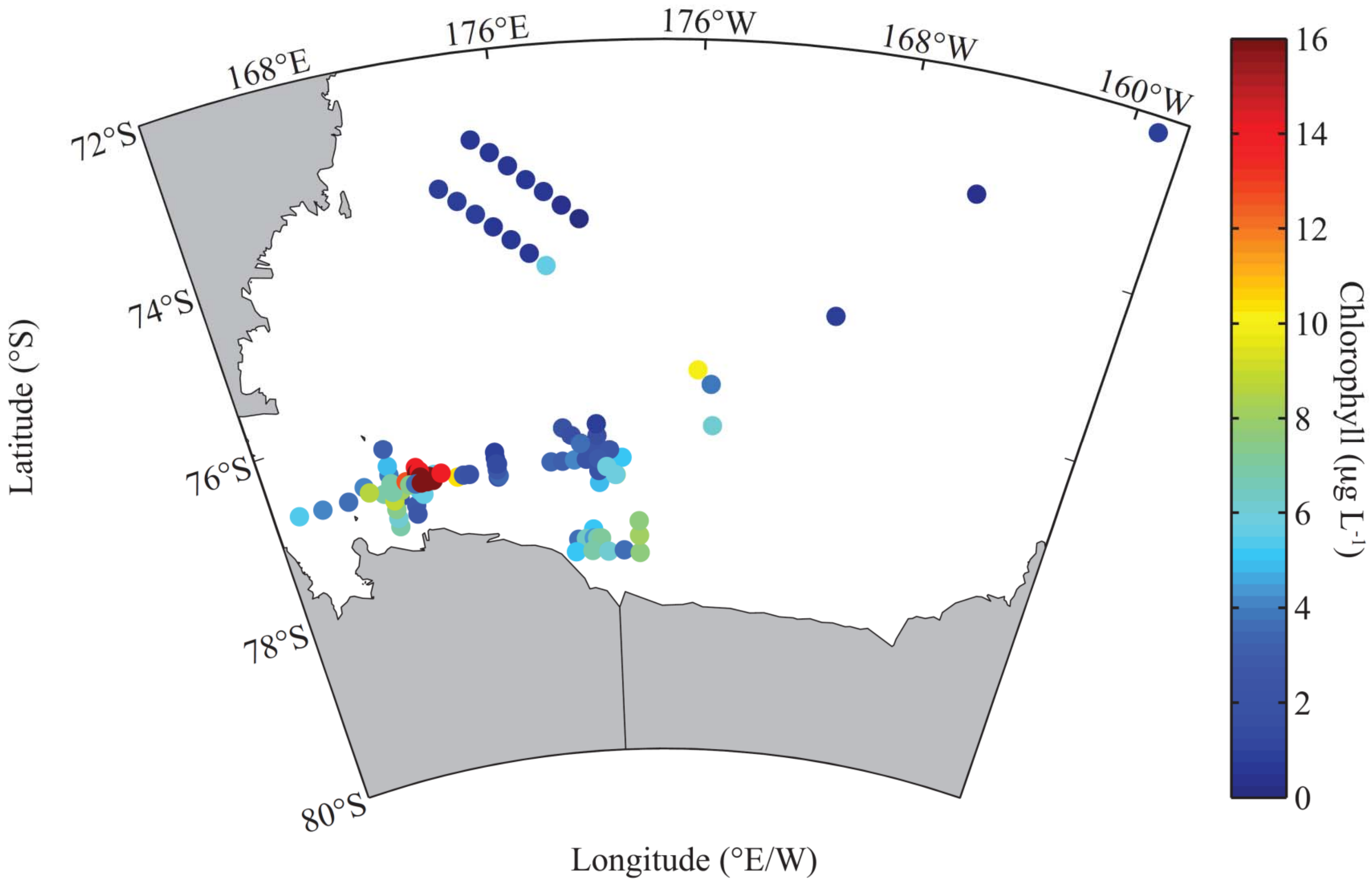
σ-type – Size of photosynthetic units

High Chl:Fe (lower iron demand)
Lower catalytic capacity

(adapted from Strzepek et al 2012)

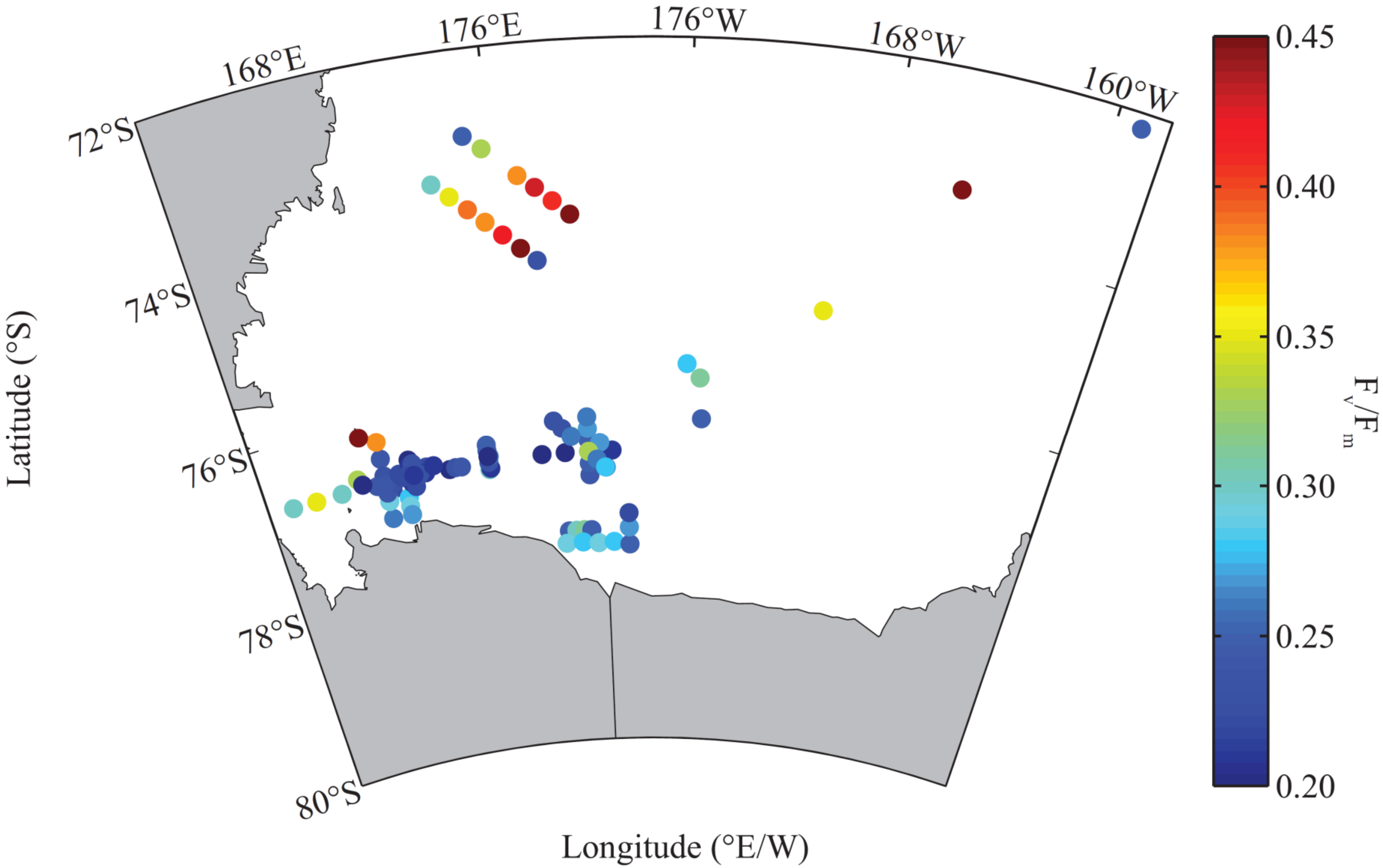


in situ Measurements: (1) Chlorophyll

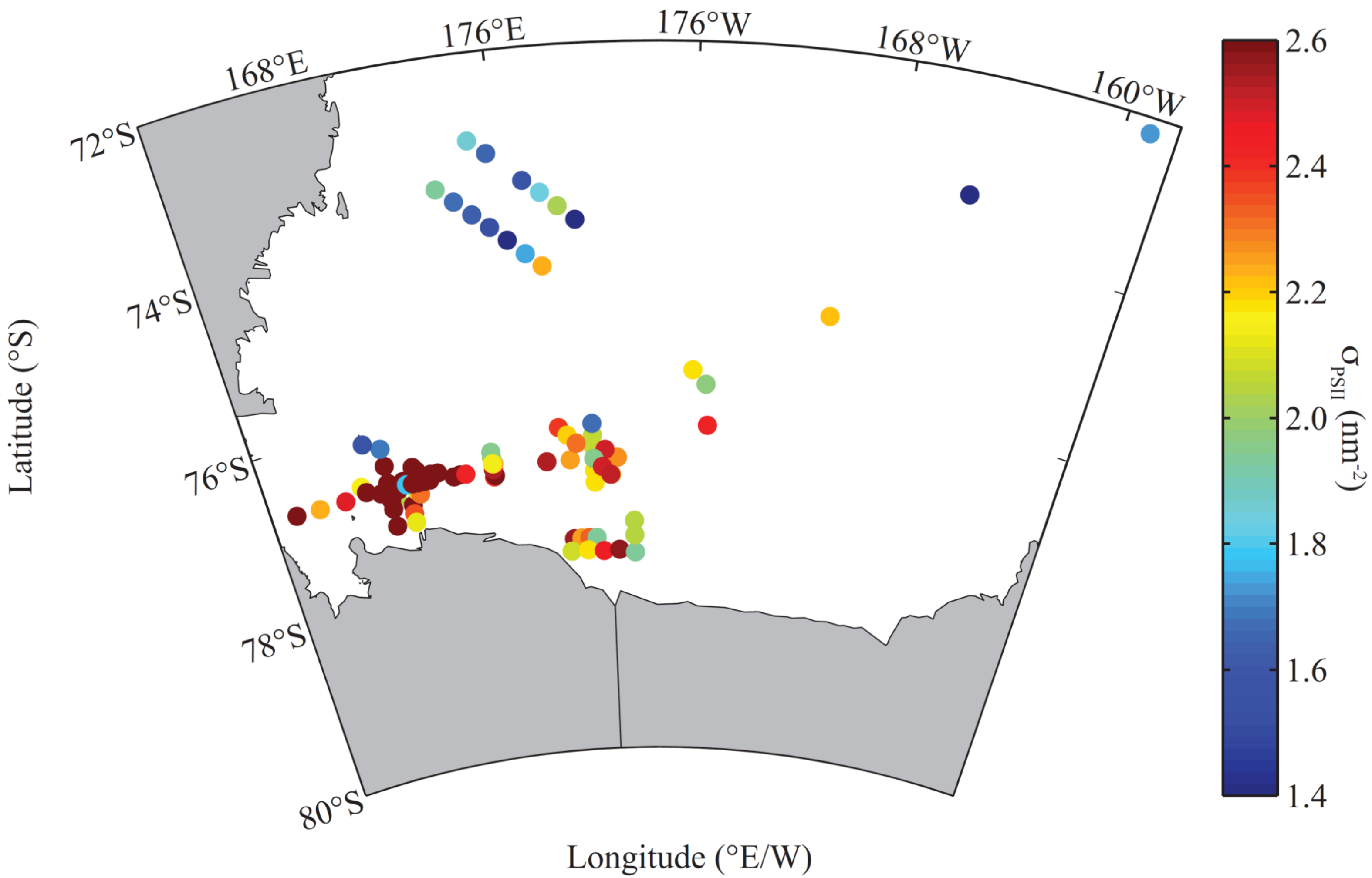


Chlorophyll data from Smith group

in situ Measurements: (2) Fv/Fm (Photosynthetic Efficiency)



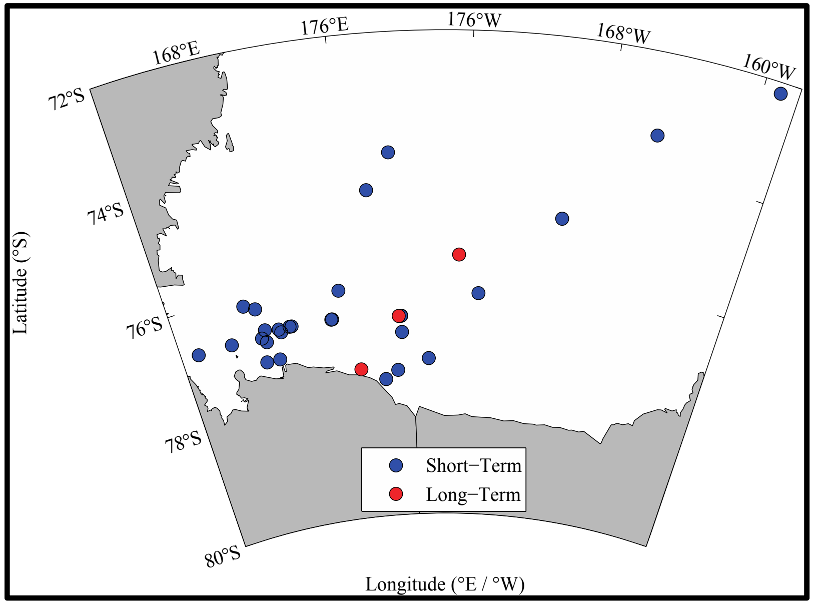
in situ Measurements: (3) σPSII (Functional Cross-section)



Bioassay Experiments (Long-Term Bioassays)

Compare phytoplankton community response to addition of 2 nM Fe

(a) Eddy
(b) Ross Bank
(c) Ross Ice Shelf

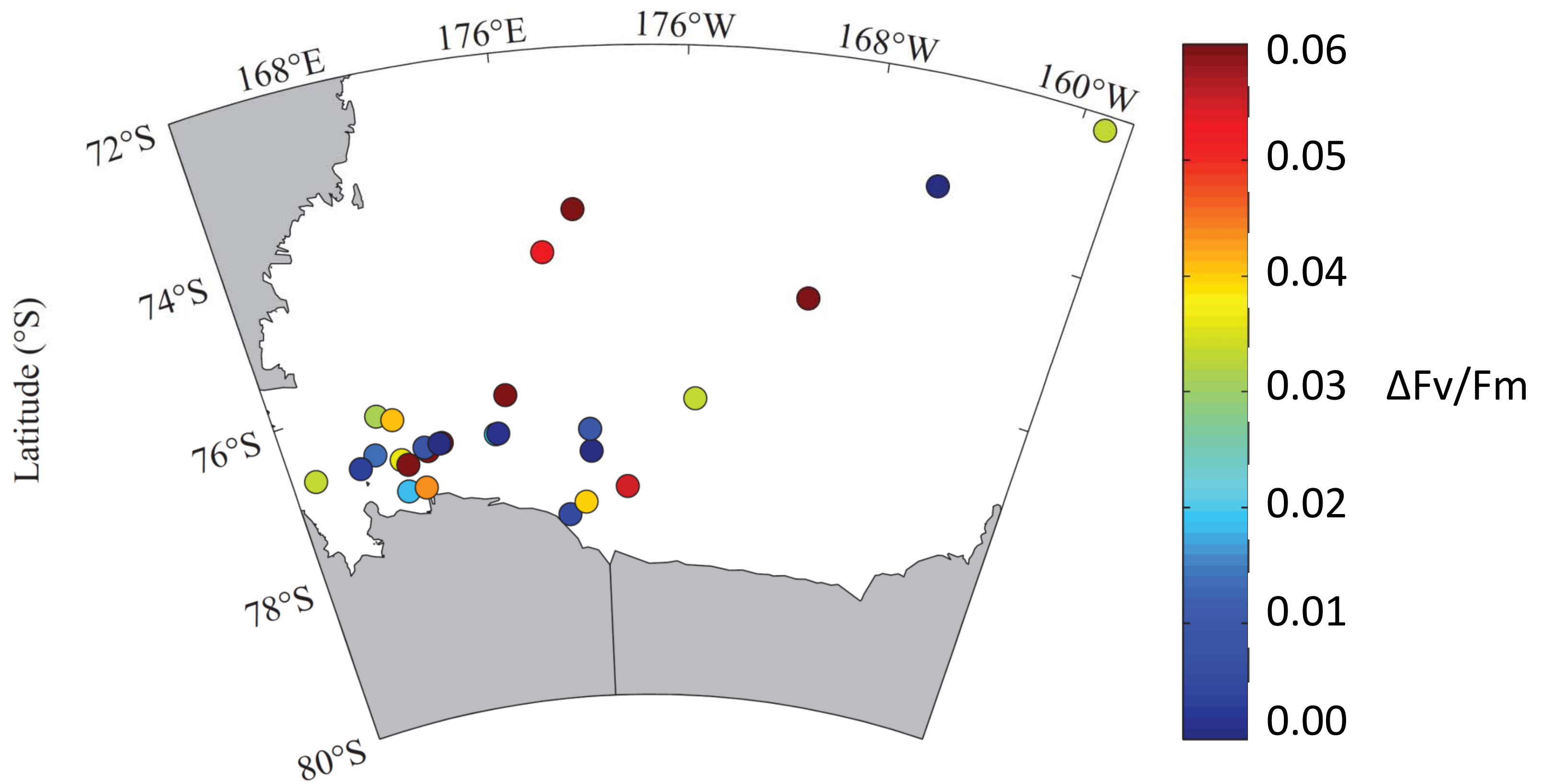


Bioassay Experiments (Long-Term Bioassays)

- All bioassays show enhanced accumulation of chlorophyll (upon Fe addition) at end of experiment
- Physiology (Fv/Fm) responds before chlorophyll accumulation
- Time taken to observe significant difference in chlorophyll accumulation is different
- Si:N drawdown is different – suggesting different community responses

	Experiment		
	1	2	3
+Fe μ^{Chl}	0.17±0.02	0.29±0.00	0.19±0.01
Control μ^{Chl}	0.12±0.03	0.25±0.01	0.13±0.01
+ Fe ΔNO_3^-	2.53±0.13	1.57±0.05	2.93±0.07
Control ΔNO_3^-	1.61±0.34	1.50±0.05	2.43±0.08
+ Fe $\Delta Si(OH)_4$	1.92±0.15	1.47±0.04	2.37±0.07
Control $\Delta Si(OH)_4$	1.24±0.29	1.57±0.08	2.43±0.06

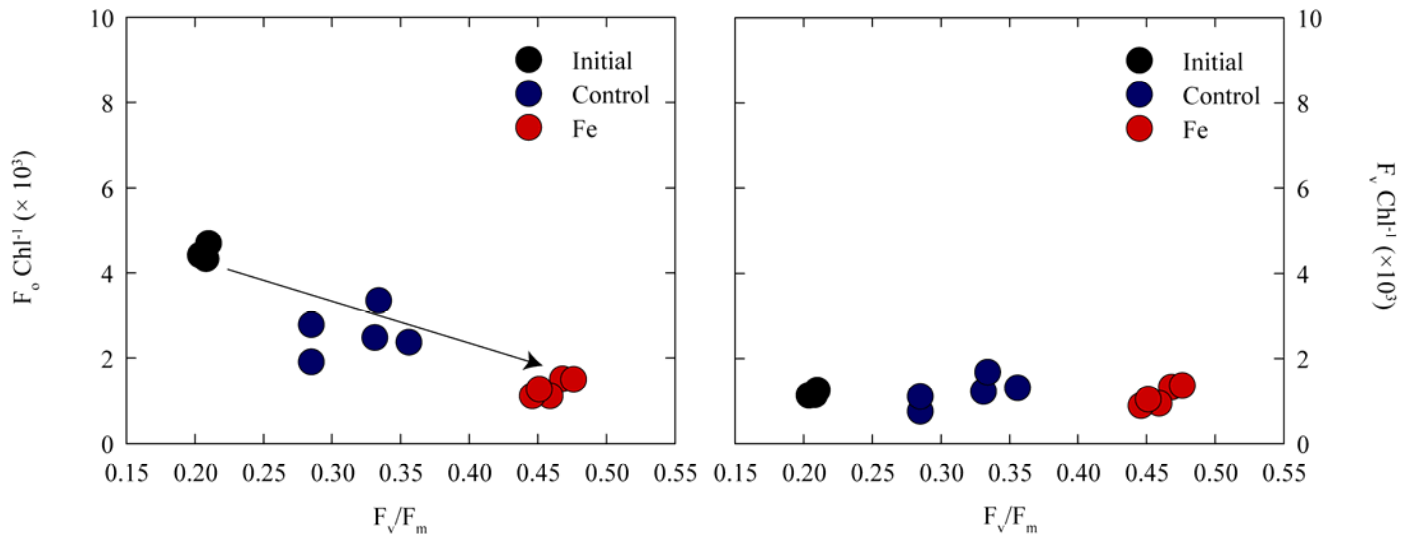
Bioassay Experiments (Short-Term Bioassays)



$$\Delta F_v / F_m = F_v / F_{m(Addition)} - F_v / F_{m(Control)}$$

Ryan-Keogh et al Limnol. Oceanogr 58(2) **2013** 533-545

Driver of physiological response to iron-limitation



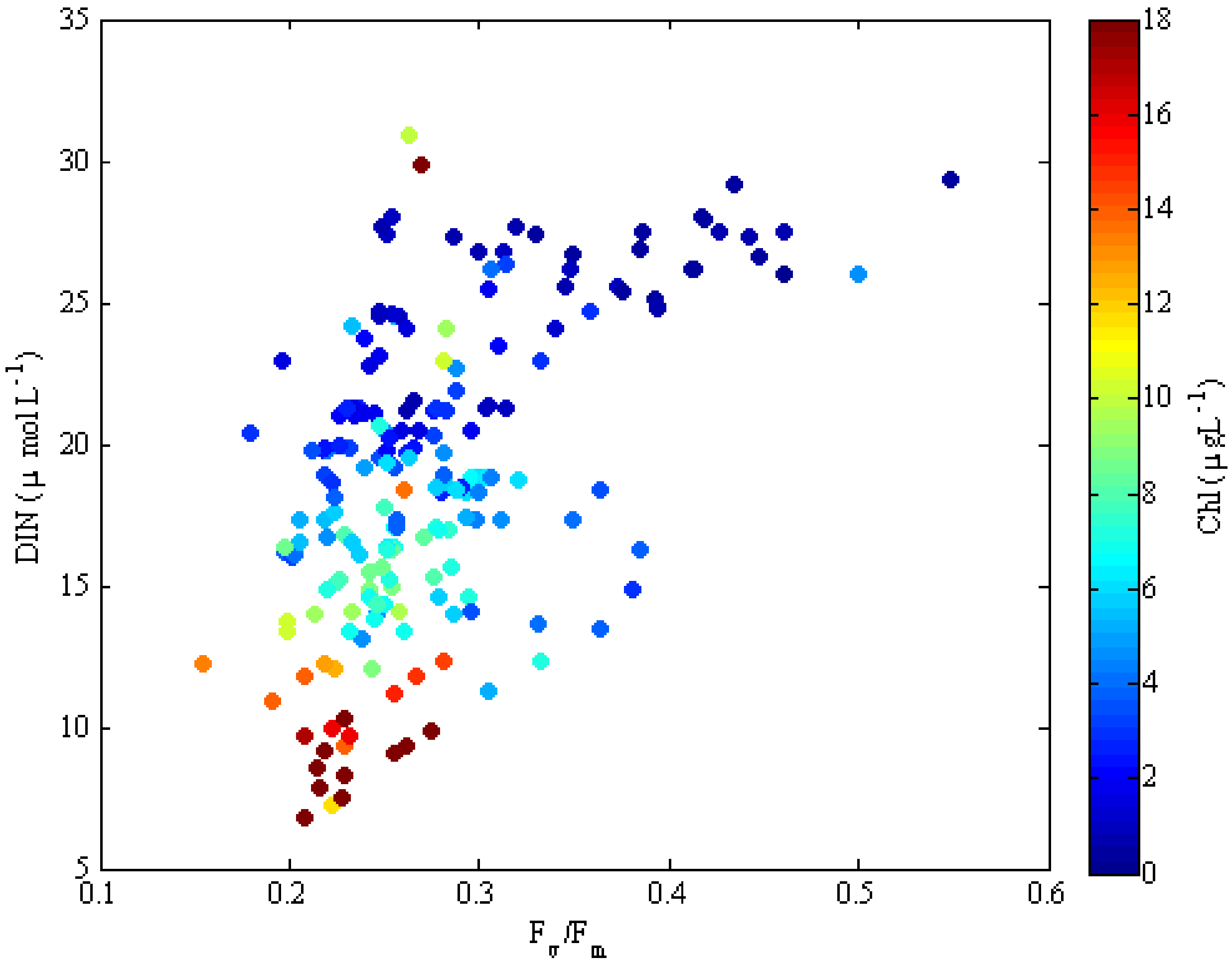
Increase of Fv/Fm upon Fe addition *(Fv = Fm-Fo)*

(1) Not driven by a change in Fv (not associated with photochemistry of PSII e.g. accumulation of damaged PSII)

(2) Is driven by change in Fo:Chl (uncoupled chlorophyll under iron stress) (*Macey et al 2014 L&O*)

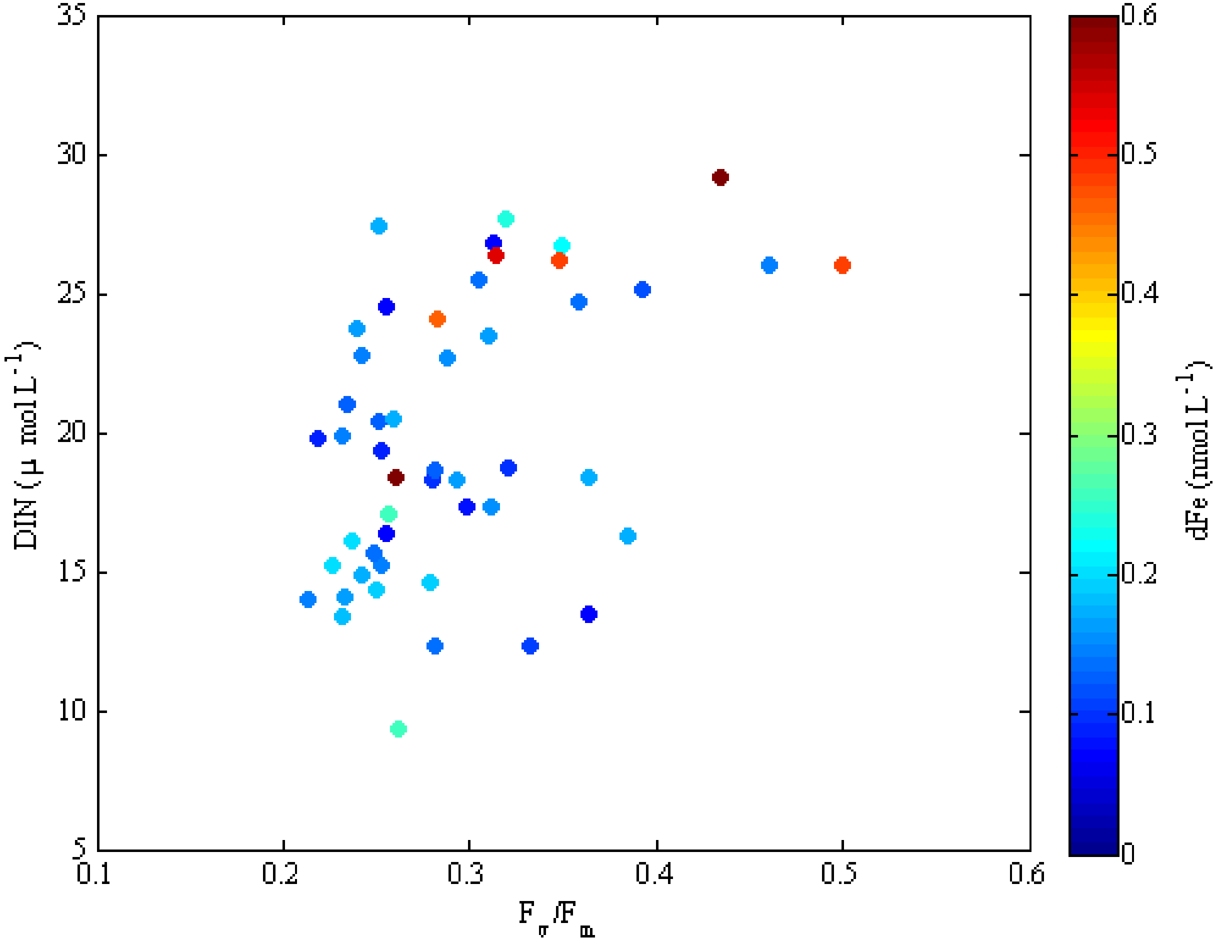
Implications: Significant fraction of Chl in Fe limited regions is not actively involved in photosynthesis.

Temporal pattern

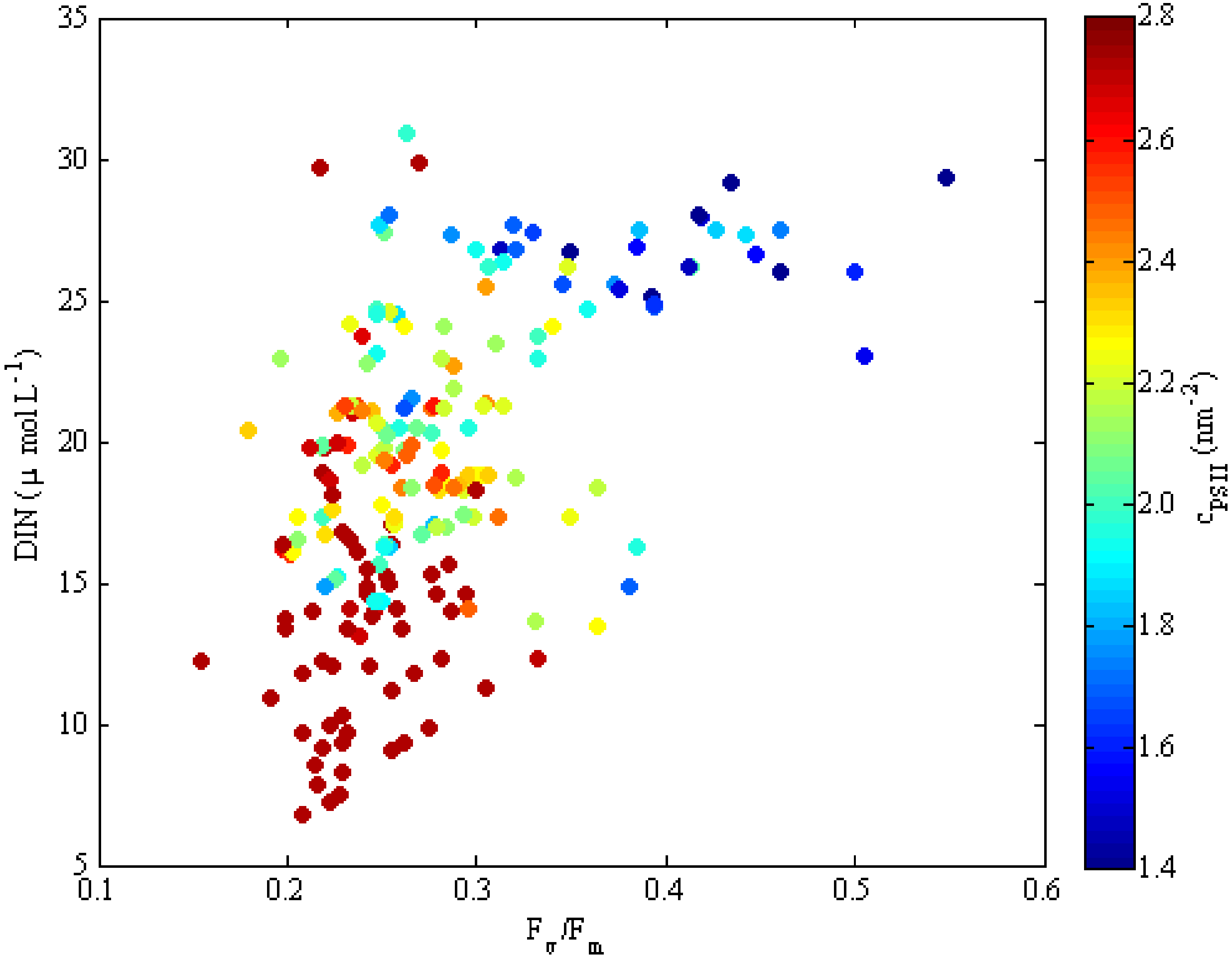


Chlorophyll (biomass) accumulates and Fv/Fm reduces as nutrients are removed

Temporal pattern



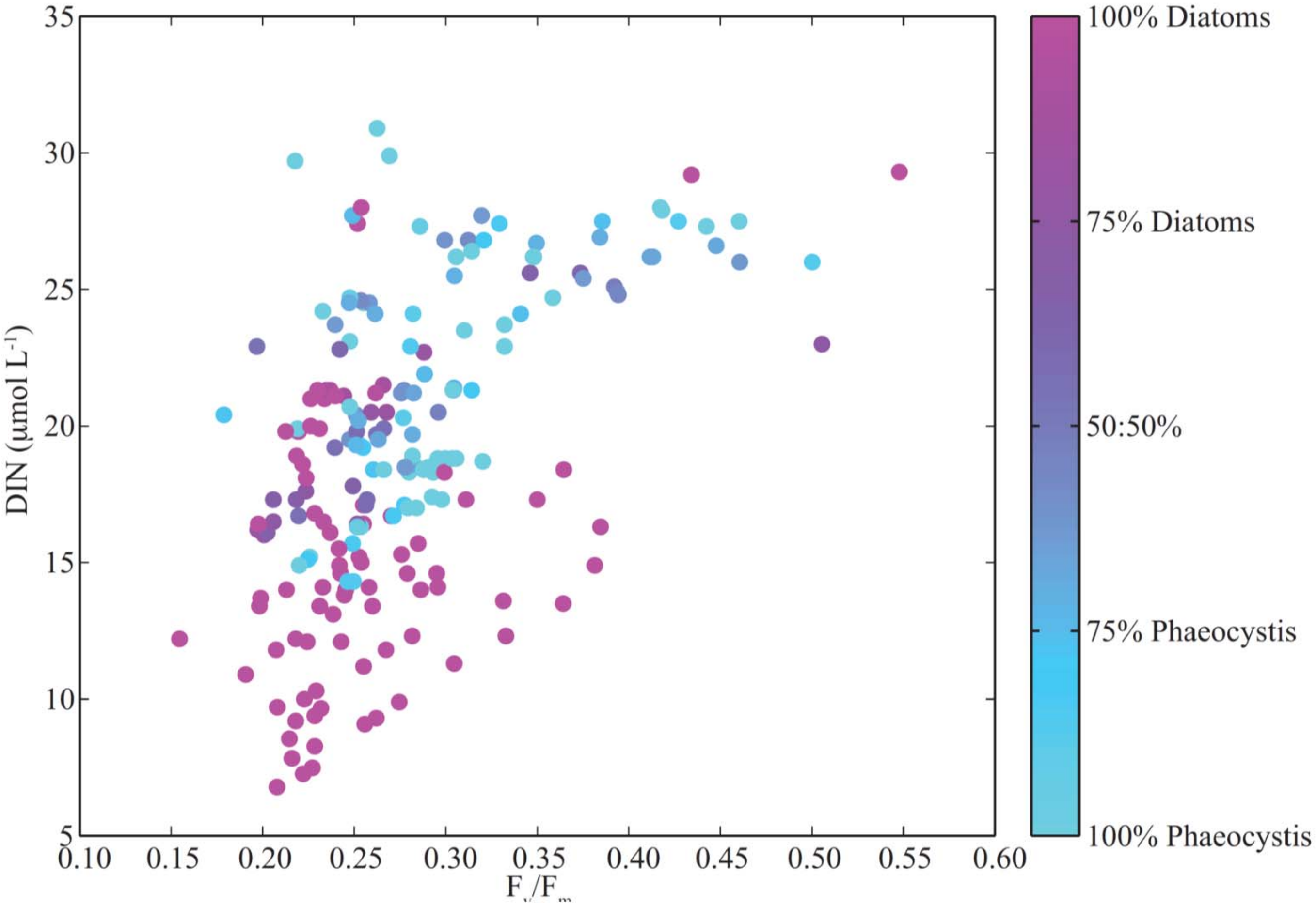
Temporal pattern



σPSII (functional cross-section) increases as nutrients are removed

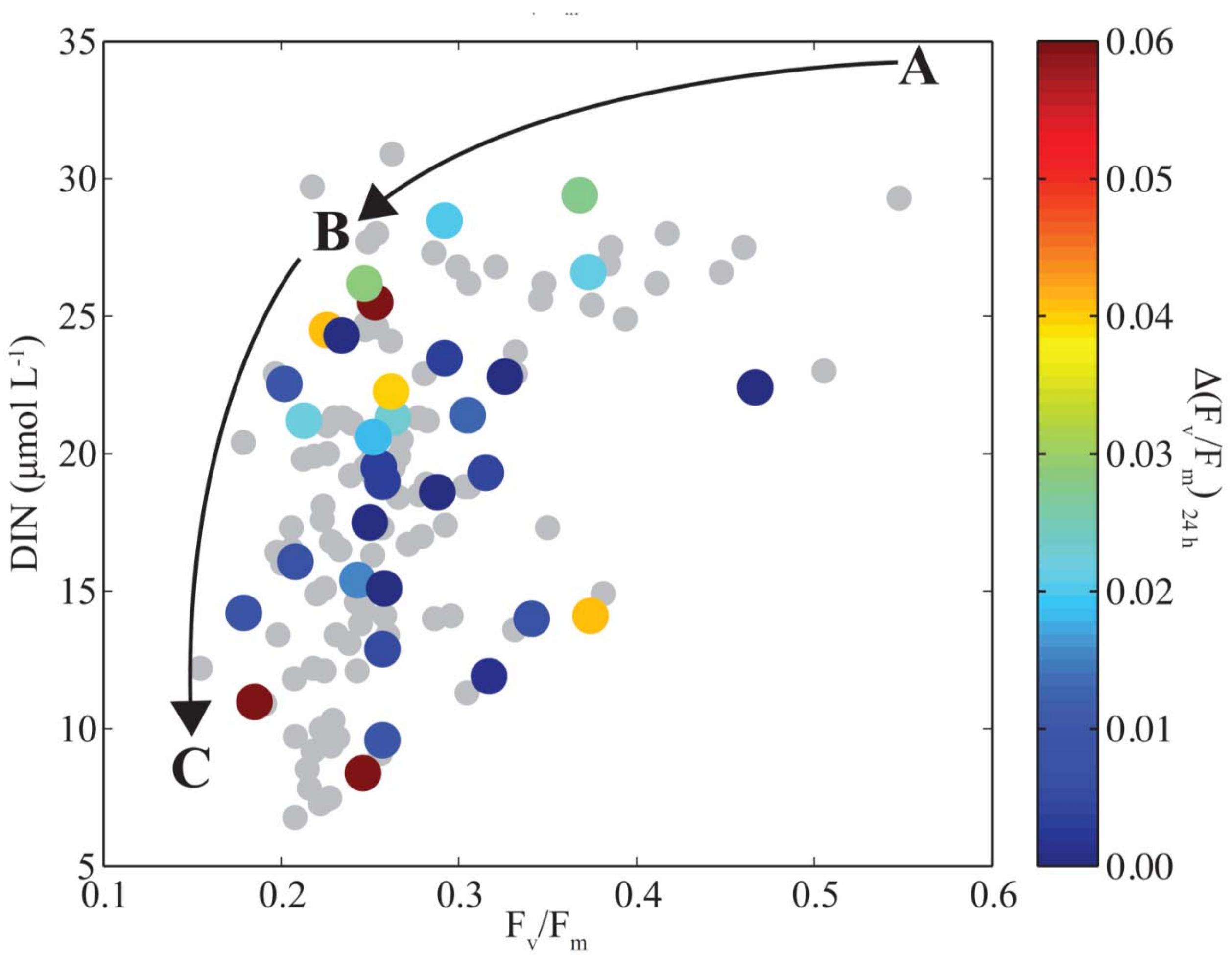
May be indicative of increase in Chl:Fe (lower cellular iron demand)

Temporal pattern



Diatoms dominate community as nutrients are removed

Temporal pattern



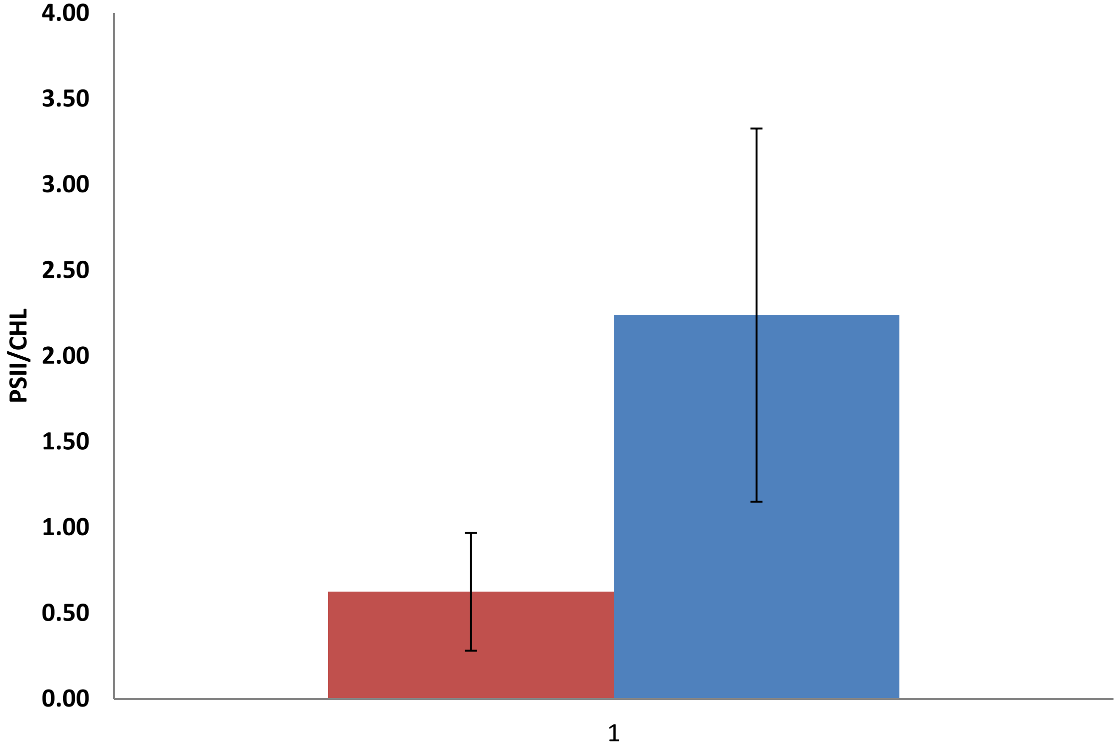
Short-term bioassay data (ΔFv/Fm) suggest two iron-stressed populations

A – No limitation

B – Phaeocystis iron stress

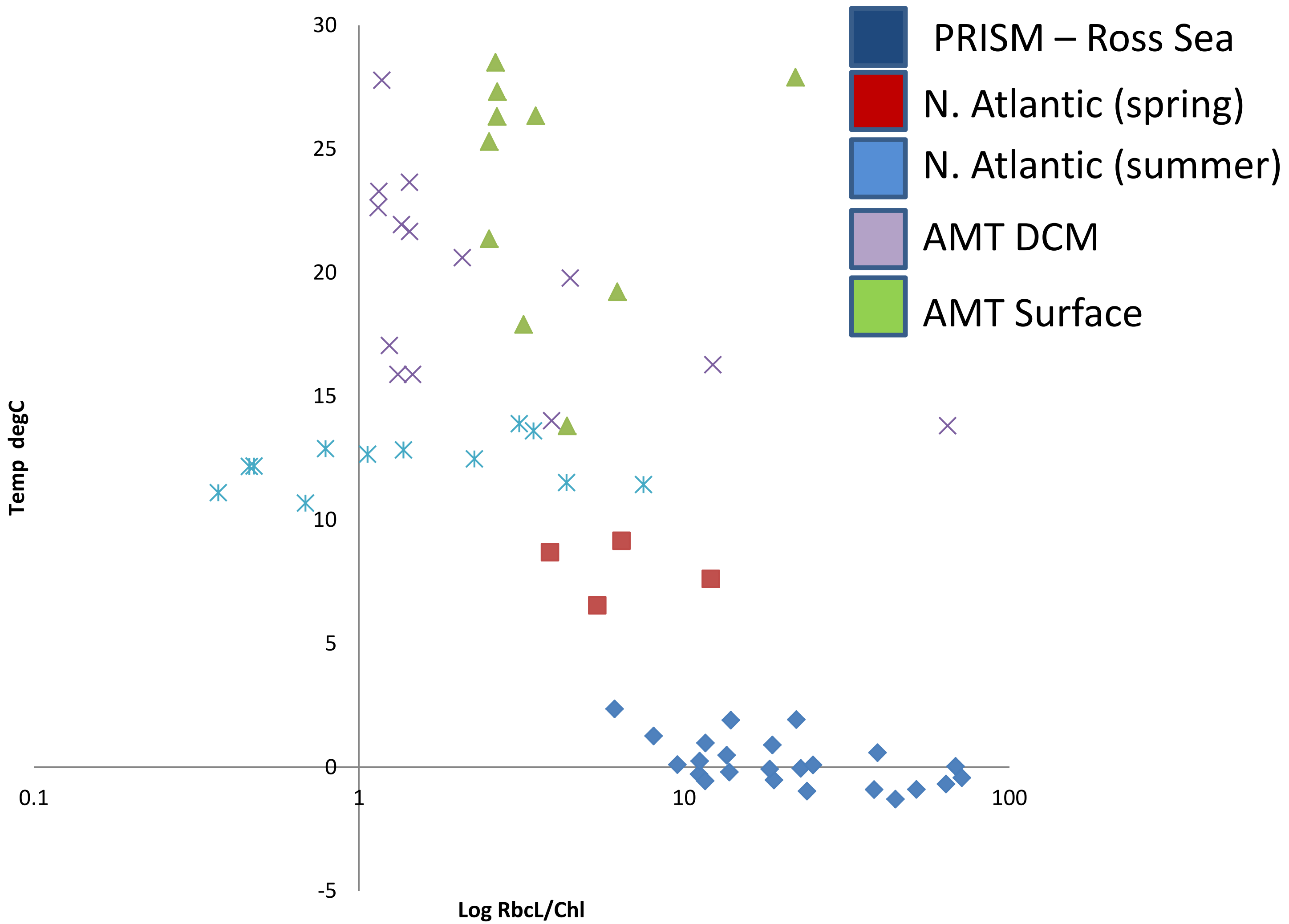
C – Diatom iron stress

PSII per Chlorophyll for (RED) Diatoms >80% community or (Blue) Diatoms <20% community



- *Reduction in photosynthetic catalysts per unit chlorophyll in diatom dominated communities*
- *Reduced Fe demand per unit Chl?*

S. Ocean phytoplankton in context



Trend in ratio of carbon-fixing enzyme to catalyst with temperature (Losh et al 2013) – RUBISCO is a small fraction of protein in phytoplankton.

Conclusions

- Suggesting temporal development of nutrient stress in Ross Sea
- Phaeocystis dominates when nitrate and iron are high (chlorophyll is low)
- Diatoms dominate when nitrate and iron are low (chlorophyll is high)
- Molecular evidence that diatoms have a reduced Fe requirement for photosynthesis (per Chl).
- Photosynthetic apparatus of S. Ocean phytoplankton seems very different from temperate/tropic species with implications for resource requirements and allocations.

Future

Papers:

(1) Seasonality of iron-limitation in phytoplankton populations in Ross Sea - Submit before December 2014

(2) Molecular basis of photosynthesis of phytoplankton communities in Ross Sea – Submit early 2015

(3) Mapping Fe limitation in Ross Sea

All datasets should be complete:

Acknowledgments:

Captain and Crew *R/V* NBP

Walker Smith (Group) –
HPLC data

Pete Sedwick (Group) –
Fe measurements